JOURNAL OF THE

SMPTE

235 The Luminance-Difference Threshold in Viewing Projected Pictures • *E. J. Breneman*

239 Methods of Appraising Photographic Systems: Part II—Manipulation and Significance of the Sine-Wave Response Function • *Fred H. Perrin*

249 Modern Control of Theater Sound • *George B. Goodall*

253 New Technology in Lighting Control Equipment • *Walter A. Levy*

256 A Wide-Band Television Switching System • *Robert S. Aha*

259 An Automatic Sensitivity Control for Monochrome Film Cameras • *S. L. Bendell and K. Sadashige*

261 Slow-Motion Recorder for Television Pictures • *H. Hiwatashi, E. Mio and T. Kitagawa*

263 Letter to the Editor: Historical Note on Composite Production of Motion Pictures • *Max Fleischer*

264 Correcting Lenses for Underwater Use • *A. Ivanoff and Paul Cherney*

267 Mobility in Underwater Cinematography • *Dimitri Rebikoff and Paul Cherney*

269 Proposed American Standards and Recommended Practice: Speed for 2-In. Video Magnetic Tape, PH22.122; Dimensions for 2-In. Video Magnetic Tape, PH22.123; Theater Screen Luminance for Indoor Theaters, PH22.124; SMPTE Recommended Practice RP7, Modulation Levels for Monochrome 2-Inch Video Magnetic-Tape Recording

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The Luminance-Difference Threshold in Viewing Projected Pictures

By E. J. BRENEMAN

The luminance-difference threshold has been determined as a function of luminance for viewing conditions similar to those recommended by the ASA for the projection of professional motion pictures. A stimulus subtending an angle of 0.5° was superimposed briefly upon various areas within typical photographic reproductions. The effective presentation time for each stimulus was about 1 second, which is near the maximum fixation time commonly occurring in the viewing of scenes and pictures. The mean luminance-difference threshold for relatively bright areas within the test scenes was found to be equivalent to a density difference of 0.015. The results indicate the nature of the dependence of the luminance-difference threshold upon the luminance of the test area and upon the luminance of surrounding areas.

THE PRESENTATION of a black-and-white photographic reproduction is basically a presentation of a pattern of variations in luminance. An observer may perceive these variations as brightness differences that serve to suggest the original scene with its analogous pattern of brightness variations. The subjective quality of the reproduction depends not only upon the physical characteristics of the photographic reproduction but also upon the conditions under which it is viewed.

The human visual mechanism is capable of adapting to a wide range of illuminance levels. Consequently, the appearance of a black-and-white photograph may change only slightly with a considerable change in the viewing conditions. However, these changes are significant, especially at the relatively low levels of illuminance used in the projection of motion pictures. As a result, a photographic reproduction which has optimum characteristics for one viewing situation (i.e., a particular screen luminance, surround luminance, angular subtense of the picture, etc.) may be considerably different from the optimum reproduction for another viewing situation. The highest quality attainable in photographic reproductions will also vary from one viewing situation to another. Thus, the problem of specifying optimum viewing conditions and print characteristics involves, basically, a study of the relationships between patterns of luminance variations comprising the picture and its surround, and the observer's impression of these patterns.

By determining the nature of the observer's perception of differences in luminance as a function of luminance of scene elements, and the changes which occur in this relationship with variations in viewing conditions, it should be possible to predict changes in print characteristics required to maintain the same subjective quality with different viewing conditions. The results of such an investigation should also indicate how the limitations of the photographic system and the human visual mechanism combine to limit the quality attainable for different viewing conditions. Thus, the results may serve as a basis for specifying optimum viewing conditions.

The work described in this paper is the initial phase of such an investigation. It serves to indicate the nature of the dependence of luminance-difference thresholds upon the luminances of the small areas within the scene and their surrounds, for one viewing situation. In addition, it establishes and describes the technique to be used in an extension of the investigation to a variety of other viewing situations.

Method and Apparatus

Luminance discrimination is so critically dependent upon a number of factors that valid information can be obtained only if the photograph-viewing situation is carefully duplicated in the experiments. Various areas within photographic reproductions should be used as test areas instead of using idealized test patterns or uniform fields. The angle which the reproduction subtends at the observer's eyes and the luminances of surrounding areas must be controlled carefully. Finally, there are temporal factors which must be considered. The luminance discrimination associated with any part of the visual field depends not only on the pattern of illuminance on the retina but also upon changes which have occurred in this pattern within the seconds or minutes prior to the instant in question. The experiments of Buswell[1] and Brandt[2] have shown that a person seldom looks at any point for more than 1 second at a time. The average fixation time is less than half a second. If luminance discrimination is determined for longer periods of fixation, there will be greater local adaptation and the results will not be applicable to the photograph-viewing situation. Of the published works on luminance discrimination known to the author, none involves a careful duplication of photograph-viewing conditions. However, a few of these works[3–7] give some consideration to the viewing of photographs.

In investigations of this type, great care must be taken to ensure that the experimental technique does not modify the psychophysical relationship being studied. It is also important that the experiment be so designed that the variance of the relationship between the observer's perception and response be small. Instructions may not be easily understood by the observer or the task he is called upon to perform may be difficult or may be unduly influenced by his mental attitude. If an observer is presented a test stimulus which is near the visibility threshold, he may be uncertain whether or not he has seen it. Blackwell[8] has found that this uncertainty exists unless the probability of a response correctly indicating the position of the stimulus is above 0.90. Consequently, an observer's response will depend on how conservative his mental attitude is

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Fig. 1. Stimulus and positioning lines. The width of the arrow subtended an angle of 0.5° at the observer's eyes. The orientation of the arrow was either up, down, right or left. The luminance of the arrow was modulated independently of that of the positioning lines.

and this may vary from day to day. Such a factor tends to lower the precision of the experiment.

A better approach is to have the observer perform some task, the success of which is dependent upon the visibility of the stimulus. This type of approach nearly eliminates the effect of mental attitude and correspondingly increases the precision of the experiment.[9] There are several possibilities in establishing such a task for the observer. Either the position, orientation, shape, or duration of the stimulus might be varied, the observer being asked to indicate which of several specified variations each stimulus represents. Only variation of the orientation of the stimulus was feasible and desirable in this experiment.

The nature of the stimuli used in this experiment is shown in Fig. 1. The width of the arrow subtended an angle of 0.5° at the observer's eyes. For each stimulus, the arrow was oriented so that it pointed either up, down, right or left. The four white lines surrounding the arrow were used to indicate the position of the stimulus within the scene.

The first observations were made with projected black-and-white transparencies under conditions similar to those considered optimum for viewing motion pictures. The screen luminance with no transparency in the projector was 10.3 ft-L. This is within the range, 9–14 ft-L, specified by the American Standard for professional motion-picture projection. Screen luminances of this magnitude are sometimes encountered also in the projection of amateur 2 by 2-in. slides. A small auditorium was used. No more than eight observers were used simultaneously in order that they might all be seated at a specified distance, 33 ft, from the screen. At this distance, the pictures subtended an angle of 19.3° horizontally and 13.0° vertically. The usual black border, the width of which subtended an angle of about 6°, was used. The ambient illumination in the auditorium was at a level too low to measure. The only significant illumination of the light-colored walls and ceiling of the auditorium was that reflected from the screen. The maximum luminance in the surround during the projection of the scene of highest mean luminance was 0.08 ft-L. This was at a point on the wall 28° from the edge of the picture.

The test stimuli were presented at various points within each scene by using a second projector. Thus, the stimulus and positioning lines consisted of increments in luminance within the scene. The ratio of the screen luminance for the scene projector to that for the stimulus projector was maintained at exactly 10:1. Consequently, the positioning lines consisted of a luminance increment of little more than one-tenth the luminance of the brightest point within the scene. The luminance increment comprising the stimulus itself (the arrow) was modulated independently of the luminance of the positioning lines. For each test area within the scene, four stimuli of different luminance increments were presented. The order of presentation of the stimuli for all test areas of the scene was randomized so that the observer never knew where the next stimulus would appear.

Each stimulus was presented for exactly 2 seconds. About half of this time was required for the observer to notice the presence and location of the positioning lines and direct his attention to the indicated location of the stimulus. Thus, he had about 1 second to look at the stimulus itself which, as noted previously, is about the maximum fixation time in the normal viewing of pictures. Presentation of the stimuli for less than 2 seconds was tried with a resultant feeling of tension and frustration by the observers. Longer presentation times would have resulted in abnormally long fixation.

Before beginning the observations, observers spent about 10 minutes in the auditorium at a low level of illuminance (indirect lighting with 0.58 ft-c on a horizontal plane) while instructions were given. The stimuli were withheld for at least 30 seconds after the beginning of the projection of each scene. Then, all the stimuli for that particular scene were presented with approximately 10-second intervals between stimuli. During these intervals, the observer was free to look at the scene in a normal manner. Each judge recorded his response on a data sheet after the presentation of each stimulus. However, he was instructed to record his response without looking down at his paper since it was important that he maintain normal adaptation by continuing to look at the projected picture.

Using the successful performance of a visual task as a criterion of stimulus visibility is straightforward only if visibility is sufficient for the performance of the task. In this experiment, it was not. The increment in luminance, ΔL_r, necessary for recognition of the orientation of the stimulus is higher than the luminance increment, ΔL_v, necessary for detecting the presence of the stimulus. Hence, the approach mentioned is valid only if a simple relationship between these two threshold increments can be established. This was investigated in the judgments of the first three scenes. The observers were instructed to give one of six responses for each stimulus. If the stimulus was visible, they were to indicate the direction (up, down, right or left) in which they believed it pointed. The instructions stressed the importance of guessing when the orientation of the stimulus was not apparent but when the presence of the stimulus was detected. A fifth response, "*X*," indicated that the stimulus was not visible. The sixth response, "*O*," was used to indicate that the observer failed to see the stimulus location as indicated by the four positioning lines.

Thirty-five observers were used with the first group of three scenes and 36 with the second group of three scenes. Very few "*O*" responses were given. Consequently, for most stimuli there were 35 or 36 usable responses. With the first three scenes, directional responses indicated that the stimulus was visible while "*X*" responses indicated that it was not. For each stimulus, the normal deviate, z, corresponding to the proportion of directional responses among the total number of responses ("*O*" responses excluded) was determined. This value was plotted as the ordinate on a graph with the increment in log luminance, $\Delta \log L$, as the abscissa. There were four such points for each test area, representing the four stimuli presented in that area. A straight line, representing a cumulative normal distribution, was drawn in such a way as to minimize the deviation of these points from the line. In doing this, the points nearest the value $z = 0$, were considered the most reliable. The straight line thus indicated the values of $\Delta \log L$ at which $z = 0$ and $z = \pm 1$ or the mean and standard deviation of the distribution. The point at which $z = 0$ represents 50% visibility of the stimulus and is denoted as $(\Delta \log L)_v$, the visibility threshold.

Similarly, the recognition threshold, $(\Delta \log L)_r$, at which the direction of the arrow was apparent to 50% of the observers, was determined. However, it was necessary to correct the proportion of correct directional responses to account for the 25% chance of guessing correctly. This was done by using the formula,

$$P_r = \frac{C - I/3}{N},$$

where P_r = proportion of observations in which the orientation of the stimulus was seen; C = number of responses

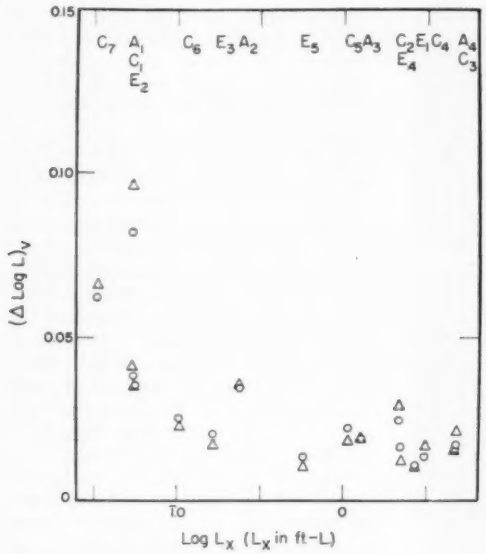

Fig. 2. A comparison of directly determined visibility thresholds, △, and visibility thresholds estimated by transforming the recognition thresholds, O.

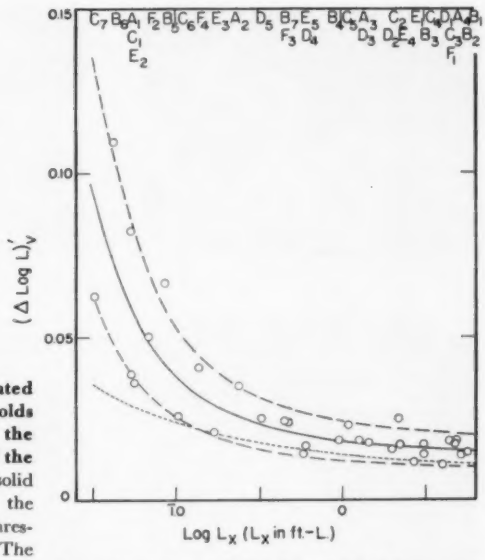
0.15
0.10
0.05
0
$(\Delta \text{ Log } L)'_V$
C_7 B_6 A_1 F_2 B_5 C_6 F_4 E_3 A_2 D_5 B_7 E_5 B_4 C_5 A_3 C_2 E_1 C_4 D_4 A_4 B_1
C_1 E_2
F_3 D_4
D_3 D_2 E_4 B_3 C_3 B_2 F_1
To
0
Log L_X (L_X in ft-L)

Fig. 3. Estimated visibility thresholds as a function of the log luminance of the test area. The solid curve represents the estimated mean threshold value. The dashed curves indicate the estimated variability due to the influence of surrounding areas. The dotted curve indicates 2.5 times the threshold found by Blackwell for a stimulus of 0.5° angular subtense and luminance, ΔL, superimposed on a uniform field of luminance, L.

which correctly indicated the orientation of the stimulus; I = number of incorrect directional responses; and N = total number of responses, including those which indicated that the stimulus was not visible. These data, thus corrected, were used to determine the thresholds and standard deviations for recognition of the orientation of the stimuli.

A comparison of the recognition and visibility thresholds for the first three scenes indicates that the two are proportional over the range of luminances occurring in these scenes. The mean value of the ratio of $(\Delta \log L)_v$ to $(\Delta \log L)_r$ was 0.596. Therefore, values of $(\Delta \log L)_r$ were multiplied by 0.596 to obtain an estimated visibility threshold $(\Delta \log L)'_v$. This value of the ratio can be considered as only approximate but it is of minor importance. Only the relative changes of the threshold which occur as a function of luminance and surround are of much significance. The transformed thresholds are plotted in Fig. 2 (circles) as a function of the log luminance ($\log L_s$) of the test area. The triangles represent the directly determined visibility thresholds. These results provide no significant evidence that the ratio of the two thresholds varies as a function of the luminance of the test area.

A comparison of the visibility and recognition data showed that, on the average, the data for recognition of the orientation of the four stimuli for a given test area were more consistent than those for the visibility of the stimuli. In addition, the results shown in Fig. 2 indicate that the variability of the directly determined visibility thresholds is slightly greater than the variability of the transformed recognition thresholds. These comparisons support the assumption that precision is increased by using the successful performance of a visual task as a criterion of stimulus visibility.

Therefore, the "X" response (stimulus not visible) was eliminated in the observations of the second set of three scenes. Thus, except in cases in which the observer could not find the position indicated by the four positioning lines ("O" response), he was forced to indicate the orientation of the stimulus whether it was visible or not. The data were reduced by the same method used for determining the recognition threshold for the first three scenes.

Results

The transformed recognition thresholds for all six scenes are plotted in Fig. 3 as a function of the log luminance of the areas in which the stimuli were presented. The values of $\Delta \log L$ at which $z = \pm 1.0$ in the cumulative normal distributions fitted to the data for each test area, were found to be approximately proportional to the values of the thresholds and may be expressed as $(1 \pm 0.46)\ (\Delta \log L)'_v$. Thus, at the point 0.54 $(\Delta \log L)'_v$, the stimulus would be visible to approximately 16% of the observers. At the point 1.46 $(\Delta \log L)'_v$, it would be visible to about 84% of the observers.

The solid curve in Fig. 3 represents the expected mean visibility threshold as a function of the luminance of the test area. Most of the variability of the thresholds about this line is assumed to be due to the influence of areas surrounding the test area. Most of the cases in which the threshold is considerably higher than the average for that luminance level are cases in which there is a bright area near the test area. Conversely, a relatively low threshold is obtained if the test area is large and uniform. The two dashed curves in Fig. 3 represent the range of recognition thresholds likely to be encountered in a group of scenes which have the variety of characteristics found in the six scenes used in this investigation. These scenes are shown in Fig. 4, with the test areas indicated by the numbered spots. This code is used in identifying the corresponding thresholds in Fig. 3.

The results indicate that at relatively high luminances, a log luminance increment of about 0.015 was required for 50% visibility of the test stimulus. This threshold increment varies only slightly over a log luminance range which extends to about 1.0 less than the highest luminances in the scenes, but it becomes much larger at lower luminances. The ordinates in Fig. 3 may also be considered as the density decrements required for 50% stimulus visibility.*

As might be expected, these results differ somewhat from those of other experiments on luminance discrimination, in which simple fields were used. The nature of their differences is consistent with our present knowledge of the effect of various factors on adaptation and luminance discrimination. The dotted curve in Fig. 3 indicates 2.5 times the threshold from Blackwell's[8] results for a stimulus of 30′ angular subtense and luminance, L, presented in a uniform field of luminance, L. The considerably greater magnitude of the thresholds found in the present work may be attributed to the shorter duration of the stimulus and to the complexity of the

* Effective density in the final reproduction.

Fig. 4. Scenes used in the determination of luminance-difference thresholds. Test areas are shown by the numbered circles. These numbers are used as subscripts of the scene letters to indicate the corresponding thresholds in Figs. 2 and 3.

surround. The influence of the surround and of continually varying local adaptation is greatest for test areas of low luminance. As may be seen in Fig. 3, the thresholds found in the present work vary with L_s in a manner similar to that found by Blackwell, except for relatively low values of L_s. At these low levels, the threshold in the present experiment is raised by the presence of bright areas in the surround.

The effect of surround luminance on luminance discrimination has been investigated by Lowry[10] and Abribat.[3] The results of such experiments are so dependent upon the size of the test field and the way in which it is viewed that a comparison with the results of the present work is difficult. However, a qualitative comparison indicates that the relatively high thresholds obtained for picture areas of relatively low luminance are of about the same magnitude as those which would be obtained with a uniform surround having a luminance which is within the luminance range of the reproduction being viewed. This is not to say that the solid curve shown in Fig. 3 could be duplicated by using an idealized test field with a uniform surround of a particular luminance. It does not seem feasible to approximate the complex field and manner of viewing in this experiment with any idealized viewing situation. However, a comparison of results indicates that the results for the picture-viewing situation do not appear to be inconsistent with those in which simpler fields were used.

The results of this and similar experiments are strictly valid only in situations in which the viewing conditions and stimuli are identical with those of the experiment. However, the author believes that, with caution, the relative changes in $(\Delta \log L)_p$, which occur as a function of $\log L_s$ may be extended to much of the "detail" which occurs in photographic reproductions viewed under similar conditions.

Conclusion

In this experiment, an attempt has been made to establish a fundamental relationship between the objective and subjective aspects of photographic tone reproduction for a viewing situation which is commonly encountered. The mean luminance-difference threshold for relatively bright areas within the test scenes was found to be equivalent to a difference in density of 0.015. The results indicate how this difference threshold increases at lower relative brightnesses and with relatively high luminances in the surround. An extension of this work to other screen luminances and other viewing situations will indicate how this basic relationship changes, and will, in turn, suggest how the characteristics of the objective reproduction must vary in going from one viewing situation to another if the subjective effect is to remain substantially unchanged. The results of an extension of the present work will also indicate how the quality attainable in the reproduction varies with changes in viewing conditions, and thus will provide useful information for specifying optimum viewing conditions.

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Discussion

Lawrence W. Davee (Century Projector Corp.): The paper presented here is interesting but I would like to suggest that the work be continued much further and related to actual presentation in the theater. Because it strikes the keynote of work which should be done in our motion-picture industry to improve our projection, I was hoping the paper was going on to draw some definite conclusions as regards theater operation. May I suggest that the work continue.

Mr. Breneman: The purpose of the paper was to present the reasoning behind this approach to the problem of improving the quality of projected pictures, and to describe the experimental procedure for this and succeeding phases of this work. The experiment must be repeated for a variety of viewing conditions if we are to learn how the viewing conditions affect our perception of projected pictures.

Methods of Appraising Photographic Systems

Part II—Manipulation and Significance of the Sine-Wave Response Function

By FRED H. PERRIN

The concept of sine-wave response is explained, and it is shown how this characteristic describes the behavior of an optical or photographic system whereas a single parameter such as resolving power or passband frequency may be inadequate. The simple experimental methods of determining sine-wave response are described, and an extensive list is given of the various methods that have appeared in the literature. The usefulness of the sine-wave response is exemplified by showing how spurious resolution may arise and how successive steps in a complete photographic system can be cascaded to give the overall response of the system. The method of computing sine-wave response from the spread function is described in detail.

CONTENTS

7. The Sine-Wave Response. . . . 239
8. Determination of Sine-Wave Response 240
9. Application and Practical Significance of the Spread Function and the Sine-Wave Response 242
10. Spurious Resolution 244
11. Comparison of Methods 245
12. The Overall Response When Printing Is Involved 246
Appendix. Computation of Sine-Wave Response 247
Acknowledgment 248
References 249

IT WAS SHOWN in Part I that the ancient and honorable concept of resolving power has been found to be inadequate as a criterion of the quality of an optical or photographic system and that at times it may even be misleading. Since any scene can be regarded as an assemblage of points of different luminous intensity, the fundamental building block of the image of any scene is the image of an infinitely small point in the scene. The distribution of illuminance within this image is known as the point spread-function. For the reasons set forth in Part I, it is more common to study the image of an infinitely narrow line — the line spread-function — and the behavior of a complete optical or photographic system can be predicted by combining or convoluting the spread function of its individual elements. Nevertheless, the numerical computations are many and tedious and are practical only with high-speed computers. A simpler method, which gives all the information required whenever only emulsions are involved and often enough information when lenses are involved, can be developed on the basis of Eq. (12).

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7. The Sine-Wave Response

It was shown in Section 6 (Part I) that if the luminance of the test object varies with distance x according to the law

$$G(x) = b_0 + b_1 \cos 2\pi\nu x, \qquad (7')^*$$

then the illuminance in the image varies according to the law

$$F(x) = b_0 + b_1 |A^\sharp(\nu)| \cos (2\pi\nu x - \phi). \qquad (12')$$

The righthand side is the Fourier transform of $G(x)$. If the subject were being treated by the theory of functions of a complex variable, $|A^\sharp|$ would be called the *modulus* and ϕ, which can be interpreted as the phase difference between object and image, would be called the *argument*, and these terms will be sometimes used here for convenience.

* Primed equation numbers are repetitions.

A comparison of Eqs. (7) and (12) shows, as was pointed out previously, that a system reproduces a sinusoidal object as a sinusoidal image but with a modulation only $|A^\sharp(\nu)|$ times as great as the modulation in the object. This factor of degradation or modulus of the transform has been given many names in optical and photographic technology, such as "optical transmission factor," "contrast-transmission function," "response function," and "line-frequency response." It will be called *sine-wave response* in this paper, and, for simplicity, it will be symbolized simply by A hereafter except when a more exact designation is required.

It is well known that, if the spatial frequency is too great (that is, if the lines are too close together), the lines will not be resolved and the response A is therefore zero. The plot of A against spatial frequency ν therefore has somewhat the shape indicated by curves A and B of Fig. 12, falling to zero at some limiting frequency.

Except for one limitation, which does not apply when only emulsions are involved and which will be discussed in more detail later, this plot is the most useful and informative characteristic of an optical or photographic system. It is exactly analogous to the acoustic response of a sound-reproducing system. It can also be regarded as the filter curve of the system, indicating the attenuation of each of an infinite series of frequencies passing through the system. Like other filter and response curves, the individual curves representing the steps of a cascaded process can be simply multiplied together to give the response of the entire system (with the restriction to be discussed in Section 12). The result gives almost as much information about the performance of the system as the tedious convolution of the various steps de-

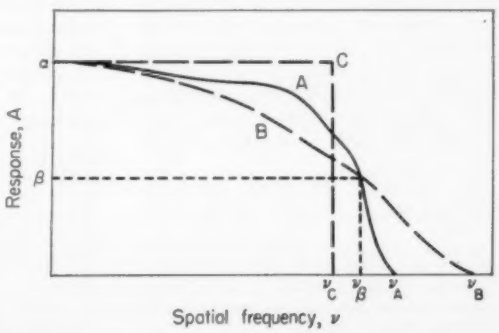

Fig. 12. Sine-wave response curves, showing reasons for deficiency of a single quantity as an index. The area under curves A, B, and C is the same, but the values of response at most frequencies are very different. Response for "true contrast reproduction" is indicated by β.

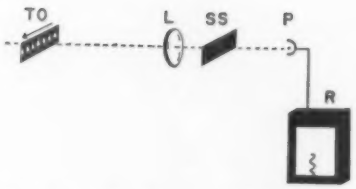

Fig. 13. Sketch of apparatus for obtaining the sine-wave response of a lens *L*. *TO*, sinusoidal test object; *SS*, scanning slit; *P*, phototube; *R*, recorder.

scribed in the preceding section, and usually in a more understandable form.

But the sine-wave response, informative and convenient though it is, is still more clumsy than a single number, and many attempts have been made to indicate the performance of optical and photographic systems by a single quantity. As was described at length, resolving power has been used for such a quantity. In Fig. 12, it represents some spatial frequency, ν_A for curve A and ν_B for curve B, beyond which the system fails to respond. This point is not likely to represent zero response but instead the response at some point near zero corresponding to the threshold of the detecting element. The reason why resolving power does not indicate the ability of the system to reproduce gross detail sharply can now be seen. Curve A shows a considerably lower resolving power than curve B, but at such a frequency as ν_C it evidently represents a better response than does curve B.

Another suggestion[29,30] that has been made is to appraise the system on the basis of the frequency ν_C that would represent the cutoff of a curve C having the same area as the curve being specified (taken here as curve A) but having a uniform response that is equal to the response α of the system at zero frequency.† Such a method of appraisal theoretically possesses the same fault of inadequacy as resolving power; curve B has the same area as curves A and C and hence the same value of ν_C, but, as just pointed out, its response for frequencies that are much above ν_C is lower. It is true that this method often works very well, but that is because the response curves are often similar in type. Spread functions frequently approximate the normal (Gaussian) distribution function,[31] and this is especially true of the overall response function of a cascaded series of processes. Thus the corresponding response curves also approximate normal distribution functions with their mean values at zero frequency.

An interesting proposal[32] has been made to use as a criterion the spatial frequency ν_β for which the response drops to its limiting value β for "true contrast reproduction." This criterion is more realistic than the resolving-power criterion, but it introduces the difficulty of determining a generally acceptable limit of "true contrast reproduction" and it gives no indication of the course of the response curve. If the limit is taken as shown in Fig. 12, it is the same for both curves A and B, which differ widely in their characteristics, as noticed previously. In short, although a single parameter may often be useful for comparing photographic systems, it may fail or even be misleading in some situations where failure may not be anticipated.[33] In mathematical terms, the response function is not one-parametric.

8. Determination of Sine-Wave Response

The general procedure for determining the response of emulsions is somewhat different from that used for lenses, and, since a lens is usually involved in studying emulsions, the methods of studying lenses will be discussed first.

The direct experimental method of determining sine-wave response is evidently to image a sinusoidal test object and scan the resulting sinusoidal image with a microphotometer. The mean value b_0 and the amplitude $b_1|A^\phi|$ in Eq. (12) can be measured on the trace. The sine-wave response is then the ratio of the modulation of the image to that of the object, which is

$$\frac{M'}{M} = \frac{b_1|A^\phi|}{b_0} \cdot \frac{b_0}{b_1} = |A^\phi|.$$

It is customary to normalize the response curve by taking the value $|A^\phi(0)|$ for $\nu = 0$ as unity, and this value can be extrapolated from the microphotometer data.

An apparatus for carrying out this procedure is sketched in Fig. 13. Here *TO* is a sinusoidal test object, *L* is the lens under test, *SS* is a scanning slit, and *P* is a phototube associated with a recorder *R*.‡ Since the slit integrates the light in its lengthwise direction, a test object of the variable-area type can be used. The recorder trace represents $F(x)$ in Fig. 10, and the amplitude of it can be read directly. By using a graduated series of test objects, the response curve can be plotted exactly as described in Section 6. It is obvious that, by using the same equipment but with a narrow slit substituted for the sinusoidal test object, the recorder will trace out the spread function of the lens.

This simple arrangement will not give the phase angle ϕ. Although it is theoretically possible to determine phase by placing a landmark on the test object, and in some of the variants of this arrangement to be described shortly this procedure is practical,[34] a better method has been devised.[27] Equation (12) can also be written

$$F(x) = b_0 + b_1 A^{\phi c} \cos 2\pi\nu x + b_1 A^{\phi s} \sin 2\pi\nu x. \quad (15)$$

Here $|A^\phi|$ and ϕ have been replaced by $A^{\phi c}$ and $A^{\phi s}$, which are discussed at greater length in the Appendix. These two new quantities are the *cosine* and the *sine Fourier transforms*, respectively, of $A(\xi)$. They can be regarded as vectors, and since they contain only cosine and sine terms, respectively, they are mutually perpendicular and are thus related to the sine-wave response function by the equation

$$|A^\phi| = (A^{\phi c 2} + A^{\phi s 2})^{\frac{1}{2}}. \quad (16)$$

Because of the perpendicular relation, the phase angle ϕ is geometrically represented by the angle between $A^{\phi c}$ and $|A^\phi|$ so that

$$A^{\phi c} = |A^\phi| \cos \phi. \quad (17)$$

Now imagine that, in Fig. 13, two test objects in the same plane are imaged on the slit, one above the other, each covering half of the slit, and that they are simultaneously moved in opposite directions.[27] The effect is to add one function $F(x)$ to the same function $F(-x)$ with a negative sign on the variable, and when Eq. (15) is written first for $F(x)$ and then for $F(-x)$ and the two expressions are added, the sine terms cancel out and the result is

$$F(x) + F(-x) = 2b_0' + 2b_1 A^{\phi c} \cos 2\pi\nu x. \quad (18)$$

The response under these conditions is $A^{\phi c}$, and this determination, combined with the determination of $|A^\phi|$ made with the single test object, enables the angle ϕ to be computed from Eq. (17).

An example of the results obtained by this procedure is shown in Fig. 14. The four graphs show, in order, the response or modulus $|A^\phi|$, the two components $A^{\phi c}$ and $A^{\phi s}$, the phase angle or argument ϕ, and the spread function $A(\xi)$. It is the highly asymmetrical and irregular character of this spread function that produces the large and rapidly changing values of ϕ.

The method of obtaining sine-wave response outlined at the beginning of this section gives excellent results but it is obviously very slow, and a more common method is to move the test object so rapidly that the sinusoidal image-traces, or even the response function itself, can be presented on an oscilloscope. Over ten years ago,[35] a method of presenting the spread function on an oscilloscope was described. An illuminated slit was

† To speak strictly, the proposal is to square each ordinate of the response curve first to give a curve that in the electrical analogue would represent power, but the criticism made here would still apply.

‡ To correspond strictly with the concept of spread function as discussed previously, the slit should be illuminated and its image — the spread function of the lens — should be formed on the test object, but there is no optical distinction between object and image when no light is lost in the imaging process. It is often convenient to use the arrangement shown, and this interchangeability of object and image will be taken for granted hereafter.

mounted on the armature of a loudspeaker and was imaged on a fixed slit by the lens under test. The speaker coil and the horizontally deflecting plates of the oscilloscope were fed by an alternating source while the vertically deflecting plates were fed by the phototube behind the scanning slit.

During the past five years, many methods of determining sine-wave response have been described. The most obvious procedure when speed is essential is to use a series of sinusoidal test objects in rapid motion. The drawback is that making sinusoidal test objects accurately is not easy. The type in which the transmittance varies sinusoidally, which is similar to the variable-density type of soundtrack, is especially hard to make, although methods have been described.[36] For determining sine-wave response, as just pointed out, test objects analogous to a variable-area track can often be used, but this type is not suitable for such purposes as measuring resolving power. Because of the difficulty of making sufficiently good sinusoidal test objects, the crenelate§ type has been commonly used for that purpose.

The crenelate type is also sometimes used for determining sine-wave response, but this procedure is open to objection unless certain precautions are taken. A crenelate pattern having lines of unit transmittance separated by opaque spaces of the same width as the lines can be represented graphically as shown in Fig. 15A. By means of a Fourier analysis,[35] this function can be represented by the pure cosine series¶

$$f(x) = 1 + \frac{4}{\pi}\cos x - \frac{4}{3\pi}\cos 3x + \frac{4}{5\pi}\cos 5x - \ldots (19)$$

This circumstance has been turned to advantage for measuring sine-wave response by rapidly moving a crenelate test object, which can be made with comparative ease, so that the phototube behind the scanning slit gives rise to an alternating current. The harmonic components can be filtered out with a narrow-pass filter and, as far as the oscilloscope is concerned, the result is the same as though a sinusoidal test object had been used.[39] It usually seems to be more convenient to use a single filter and explore the field of spatial frequencies by varying the speed of the test object so that the pass-frequency corresponds to

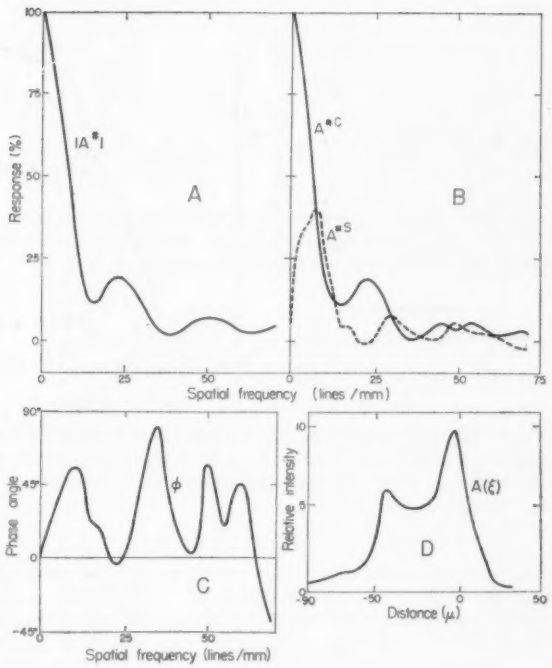

Fig. 14. Sine-wave analysis of a certain spread function. A, sinewave response or modulus of Fourier transform; B, sine (A^{fs}) and cosine (A^{fc}) transforms; C, phase angle or argument of Fourier transform; D, spread function from which the analysis was made.

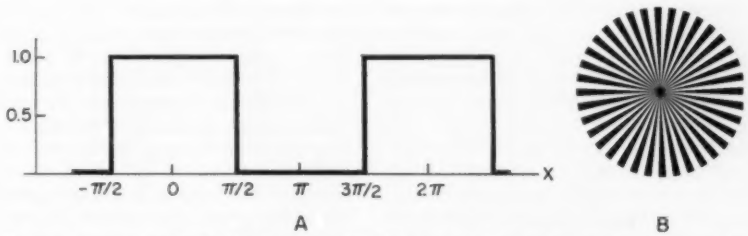

Fig. 15. A, crenelate light distribution with distance coordinate in angular measure for convenience of making the Fourier transform; B, pie-chart type of test pattern.

first the fundamental spatial frequency, then the second harmonic, etc.[40–42] A type of test object that is especially convenient is the sunburst or pie pattern (known in Europe as the "Siemens star") shown in Fig. 15B. This can be rotated and the phototube current filtered as just explained.[43]

One way of determining the phase of the response in connection with the devices that have just been described is to use a comparison beam that passes through a good objective and forms an image on the axis. The spread function of such a lens on the axis is symmetrical and therefore the response is in phase with the object for all frequencies.[39,44] When the pie chart is used, it can be mounted in a toothed ring and a pickup coil near the moving teeth will then furnish the impulses for the time axis of the oscilloscope.[45]

An ingenious method of continuously recording the sine-wave response of lenses has been described[46] in which the test object consists of two halftone screens in contact that are rotated with respect to each other in their own respective planes to vary continuously the angle between the lines. The result is a moiré pattern whose spatial frequency varies with the angle between the lines and whose light distribution is very approximately sinusoidal. If the angular speed with which the screens are rotated is held constant, a sinusoidal image of varying spatial frequency passes across the scanning slit at a constant rate. A second slit picks up light from the screen combination itself, and the two beams of light impinge on a phototube. A cathode-ray oscilloscope associated with the phototube displays a curve of the amplitude of the image relative to that of the object against spatial frequency, which is to say that it displays the sine-response curve. Since the phase in the image relative to that in the object is also known, the oscilloscope can be arranged to display the relative phase against spatial frequency by means of a second electron beam.

Another way of impressing a sinusoidal pattern[47] is to form an image of a slit and sweep this image across the field with a rotating mirror. Two polarizers

§ The term "square wave" is frequently used for this type of pattern, but in the case of photographic test objects, any resemblance to a wave is rather far-fetched and the writer prefers the precise dictionary term "crenelate," which has been used by at least one other writer.[37]

¶ The equivalent equation is given in numerous works on Fourier analysis for the origin at the edge of the line instead of the center. The expression is the same except that each cosine becomes the corresponding sine and all the terms are positive.

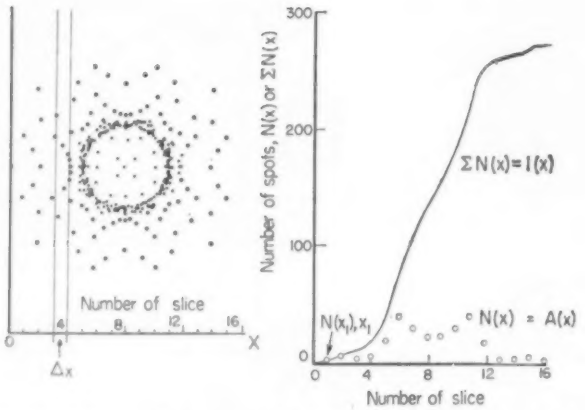

Fig. 16. Left, spot diagram partitioned into equal slices along x-axis. Right, plot of number of spots $N(x)$ in each slice (small circles) and cumulative number $\Sigma N(x)$ (curve) against number of slice. Each slice has a width of 12.5μ.

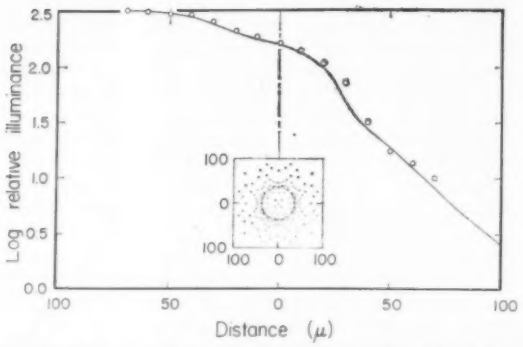

Fig. 17. Edge trace determined experimentally with finished lens (curve) compared with values computed from design data as indicated by Fig. 16 (small circles). The abscissa scale of the graph is ten times that of the spot diagram; the ordinate scale is logarithmic.

are placed in the beam, one that is fixed and one that rotates rapidly compared with the speed of the mirror, so that the illuminance in the slit image varies sinusoidally.

It is possible to measure sine-wave response and phase by imaging a slit on a stationary sinusoidal test object with the lens being tested.[48] The procedure is to measure the total amount of light transmitted by the test object, move the test object to another position (most conveniently one-quarter of a cycle away), and make another measurement. From these two measurements, both the response $|A^{\phi}|$ and the angle ϕ can be determined, but the mathematical techniques required are beyond the scope of this treatment.

Interferometers are also used to measure sine-wave response.[49–51] When two beams from a single source (a slit or pinhole) are brought together, they either reinforce each other or tend to neutralize each other, depending on whether they are in the same or opposite phases. When the path difference between two such beams varies linearly with time, a sinusoidal signal of known amplitude and phase is generated, and if the beams come from the lens under test, the amplitude is the modulus and the phase is the argument of the desired Fourier transform. The apparatus is a shearing interferometer,[52] and the amount of shear determines the spatial frequency. The details of the procedure require mathematics that are beyond the limits of this paper.

Another interesting method of determining sine-wave response makes use of a "white-noise" generator.[29,30] If the lens could be presented with signals having a frequency range running the gamut from zero to infinity, the sine-wave response could be obtained by measuring the output, frequency by frequency, with a wave analyzer. Such a white-noise generator is to be found in a photographic film developed to a moderate density.[53] A photographic image in an emulsion of moderate intrinsic gamma contains grains of a wide range of sizes, and this circumstance, combined with the random distribution of the grains, gives rise to a granularity trace that contains a very wide range of frequencies. By using a uniformly exposed and developed photographic film as a test object, therefore, and scanning the image, an analysis of the phototube output should give the sine-wave response of the lens that formed the image. The experimental difficulty is that the amount of energy represented by each narrow band of frequencies that is measured at a given time by the analyzer is very small, and hence the analysis is of low precision. Another method is to connect the scanning phototube with a recorder to make a granularity trace, which is then analyzed mathematically. The method of doing this involves autocorrelation analysis and cannot be considered here.

Photographic emulsions are harder to measure than are lenses in the sense that the response of the optical system used to impress the optical image on the emulsion must be taken into account. The photographic image can be scanned with a microdensitometer and the "effective" image can be determined by working backwards through the characteristic D-log E curve. The resulting response curve represents the combined response of the emulsion and the lens, but if the response of the lens is determined as just described, this response function can be divided into the combined response function to give the sine-wave response function of the emulsion. Recent experiments have proved the soundness of this procedure.[54,55]

It is to be emphasized that the sine-wave response and the spread function of an emulsion refer to the distribution of the *effective exposure*. In the references cited, the emulsion is used as its own photometer so that the developer effects are unimportant as long as they are constant. Such photographic effects as cross modulation, which are evaluated in terms of density and not exposure, depend on the conditions of development in addition.

So far, methods of obtaining the sine-wave response from the spread function have been discussed. By methods that cannot be elaborated here, the spread function can be obtained from the sine-wave response; mathematically, this procedure is equivalent to obtaining the Fourier transform of the sine-wave response, since the Fourier transform of a transformed function is the original function. There is one qualification to the statement of this mathematical equivalence. It concerns the argument or phase angle ϕ in Eq. (12), because the sine-wave response refers to the modulus alone and not to the argument, both of which are involved in a Fourier transform. When the spread function is symmetrical, the image is in phase with the object and the argument ϕ disappears for all frequencies, as demonstrated in the Appendix. When the spread function corresponding to the sine-wave response is not symmetrical, ϕ must be taken into account because in general it varies with frequency. This is usually the case for lenses, whose aberrations are unsymmetrical except on the axis, as shown by Fig. 7. For emulsions, whose spread functions are symmetrical, ϕ is always zero although, of course, this may not be true for a combination of an emulsion with a lens.

9. Applications and Practical Significance of the Spread Function and the Sine-Wave Response

The performance of an optical system can be predicted in terms of its spread function even before the system has been constructed. Imagine the entrance pupil

of the system to be covered by an opaque plate that is pierced with a large number of small holes uniformly spaced. From the design data of the system, a ray can be traced from the object point through each of these holes, and its intercept on the assumed image plane can be found.[56] With diffraction neglected, as is customary in lens design, all the rays would come to a point on the image plane if the lens were perfect. Actually, they form a pattern like those shown in the upper part of Fig. 7. Since the holes in the perforated stop were assumed to be uniformly spaced, the density of the spots in this diagram indicates the concentration of light in the image,[57] which means that this spot diagram is a graphical representation of the point spread-function.

To evaluate this spot diagram, it can be partitioned into small vertical slices of equal width Δx, as indicated in the left-hand sketch of Fig. 16. The number of spots $N(x_1)$ in the first slice is plotted at x_1 in the graph of number N against distance x or the serial number of the slice at the right, the number $N(x_2)$ in the next slice is then plotted at x_2, and so forth. The final result is a curve $N(x)$ (not drawn in Fig. 16), which is clearly also the line spread-function $A(x)$. The cumulative curve, obtained by plotting $N(x_1)$, $[N(x_1) + N(x_2)]$, and so forth, represents the integral of this curve and hence the edge trace $I(x)$. All the data are now at hand in the conventional form for computing such quantities as acutance and sine-wave response. Figure 17 shows the edge trace so obtained (small circles) compared with the trace made from the finished lens (solid line). It is evident that the performance of the lens was satisfactorily predicted.

A deeper insight into the meaning of these concepts can be gained by considering a concrete example. Figure 18 shows at *A* two hypothetical spread functions. They have been selected simply because they are well-known mathematical functions, namely, the normal or Gaussian error distribution function with different constants, but spread functions of these general types are encountered in practice. Curve *a* represents the simple function

$$A_a(x) = e^{-\frac{1}{2}(0.125x)^2}$$

while curve *b* represents the composite function

$$A_b(x) = 0.50\, e^{-\frac{1}{2}(0.50x)^2} + 0.50\, e^{-\frac{1}{2}(0.05x)^2},$$

the first term representing the narrow neck of the curve and the second, the flaring skirt. Tables of the normal distribution function are available in which the argument is a quantity σ, known as the *dispersion* or the *standard deviation*. For curve *a*, $\sigma = 1/0.125 = 8$, while for curve *b*, $\sigma = 1/0.50 = 2$ and $1/0.05 = 20$ for the two terms, respectively.

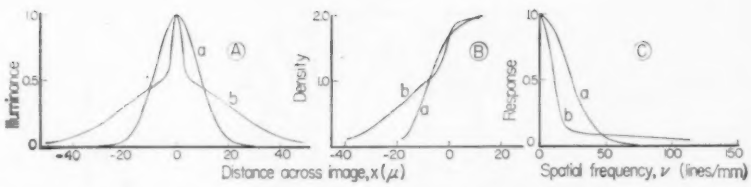

Fig. 18. A, two hypothetical spread functions used as examples. (*a*) Simple error function; (*b*) sum of two error functions of different dispersion. **B, edge traces computed from spread functions *a* and *b* in A. C, sine-wave response curves computed from spread functions *a* and *b* in A.**

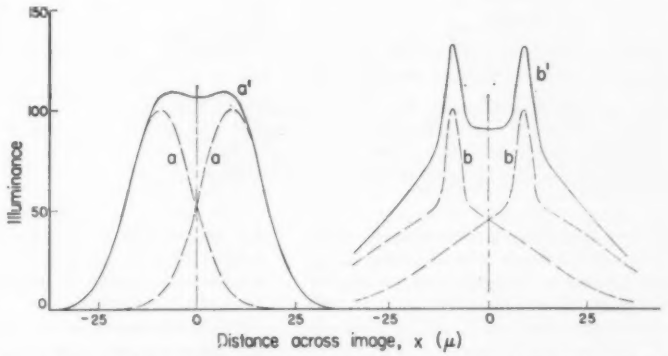

Fig. 19. Summation of two spread functions of type *a* in Fig. 18A (left) and of type *b* (right). The separation is such as to make the minimum of the composite curve *a'* practically equal to the maxima.

Figure 18 shows at *B* the corresponding edge traces, computed by summation as described in Section 5 (Part I). The summations were made for the spread functions themselves, then the light distributions thus derived were combined with the characteristic curve of an actual photographic emulsion to determine the photographic effect for that particular emulsion processed in one particular way. The width of the original spread function was selected so as to be representative of practice, and therefore these edge traces are also reasonably representative of practice. It will be noticed that curve *a* is simple in shape, while curve *b* is steep near the center but has a low gradient over a large part of the toe and shoulder. The acutance values of these curves are 2700 and 1240, respectively, which indicates that the low gradient in the toe of curve *b*, arising from the flaring skirt of the spread function, is effective in holding down the acutance of the system despite the high gradient at the center of the trace.

At *C* are shown the sine-wave responses corresponding to the two spread functions, obtained as described in the first paragraph of the preceding section. This figure shows that system *a* is superior in reproducing details that correspond to frequencies lower than about 50 lines/mm but that system *b* will produce resolution where system *a* fails. This effect is graphically shown in Fig. 19, which represents the summation of two spread functions whose separation $\Delta = 1/55$ mm is such that the illuminance of the composite curve *a'* between the two spread functions *a* is approximately equal to the illuminance in the two maxima. At this separation, the illuminance in the center of pattern *b'* is 30% lower than at the two maxima and the two spread functions are clearly resolved. This example shows the little relation that resolving power and acutance bear to each other, and that resolving power is not a criterion of the clarity with which large details are reproduced.

This distinction between resolving power and sharpness has been occasionally mentioned in the literature. It was foreshadowed by the observation of an amateur astronomer, Rev. W. R. Dawes,[5] about 1830, that a telescope with a $2\frac{3}{4}$-in. objective having a "wretched figure" nevertheless separated closer double stars than a "perfect little glass" of $1\frac{5}{8}$-in. aperture. Of course, the poorer glass showed a large amount of "fluff" around the image. For another instance, at the turn of the century,[58] the suggestion was made that image quality might be improved by enhancing contrast at the expense of resolving power.

This distinction has been noticed in connection with modern quantitative studies,[43] and a practical case has been described in the pages of this *Journal*.[19] In this case, one photograph, made with a spread function having a flat top and steep sides, showed high sharpness but low resolving power, while the com-

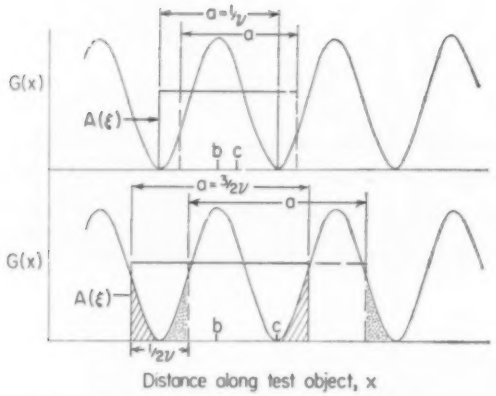

Fig. 20. Sketch illustrating how pseudoresolution can occur when a crenelate spread function is convoluted with a sinusoidal object function. Above, width of spread function $a = 1/\nu$; uniform illuminance in image. Below, $a = 3/2\nu$; pseudoresolution.

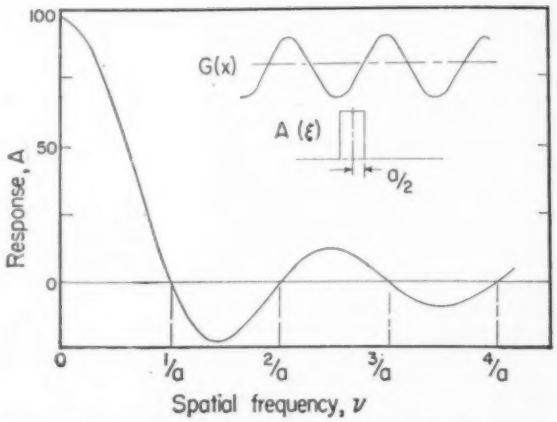

Fig. 21. Sine-wave response of crenelate spread function. Negative values represent pseudoresolution.

panion photograph, made with a spread function having a narrow neck but a flaring skirt, showed low sharpness although the resolution of the extremely fine details was good.

10. Spurious Resolution

The sine-wave response also throws light on the phenomenon of *spurious resolution* or *pseudoresolution*. One simple case can be studied on the basis of the material that has been presented earlier. In the upper sketch of Fig. 20, let $G(x)$ be the object function representing a line test-object in which the transmittance varies sinusoidally between zero and a maximum. Let $A(\xi)$ be a crenelate (square-topped) spread function centered at b on the test object. The convolution of this spread function with the object function for this position gives a certain illuminance $F(x)$ in the image. Now let the spread function be moved by an arbitrary distance so that its center is at c, as shown by the broken lines. If the width of the spread function $A(\xi)$ equals the width of a single line-element of the object $G(x)$, or $a = 1/\nu$, as drawn, a little reflection will show that the value of the convolution in the new position c, wherever c may be, will equal the value at the former position b, and thus the illuminance $F(x)$ is uniform over the entire image. The same result is clearly obtained when the width a of the spread function equals the width of any other integral number of line-elements.

Now consider the lower sketch in Fig. 20, where the spread function encompasses one and one-half line-elements, or $a = 3/2\nu$. When the spread function is centered on a maximum, like b, as shown by the solid lines, it encompasses one complete line-element plus the hatched portions of the two adjacent ones. Each hatched portion can be shown to have an area that is 9.1% of the total area of the graph for one line-element, so the relative illuminance in the image at b is $1 + 2 \times 0.091 = 1.182$. When the spread function is centered on a point of minimum transmittance c, as shown by the broken lines, it encompasses two line-elements less the two dotted areas, each of which represents 9.1% of the area represented by a complete element. The illuminance in the image, therefore, varies from 1.182 to $2 - 2 \times 0.091 = 1.818$, which means that the image consists of a line pattern having an illuminance ratio of 1.818/1.182 = 1.54. However, the maximum illuminance comes at the position that should be represented by a minimum, and since this does not correctly reflect the distribution of luminance in the original test object, the resolution thus produced is said to be spurious.

This example can be also treated mathematically. The spread function $A(\xi)$ is uniform from $-a/2$ to $+a/2$, as shown in Fig. 21, and its amplitude can be taken as equal to unity. When it is convoluted with the sinusoidal function $G(x)$, as indicated by Eq. (10), the Fourier transform is found to be

$$|A^{\natural}(\nu)| = \frac{a \sin \pi\nu a}{\pi\nu a}. \qquad (20)$$

This quantity $|A^{\natural}(\nu)|$ is the sine-wave response as before, and it is plotted against spatial frequency in Fig. 21. The regions where the curve goes below the axis are the regions of pseudoresolution, the negative values of A meaning that the lines and spaces in the image are in the opposite phase from those in the object, so that lines appear where spaces should, and *vice versa*. This curve represents only the varying part of the illuminance in the image; there is, of course, a constant illuminance superposed on this varying part, and thus the frequencies for which $A = 0$ in Eq. (20) have a uniform density greater than zero. The illuminance ratio between the images of lines and spaces diminishes for the successive minima and maxima in Fig. 21 until the illuminance becomes sensibly constant and resolution fails.

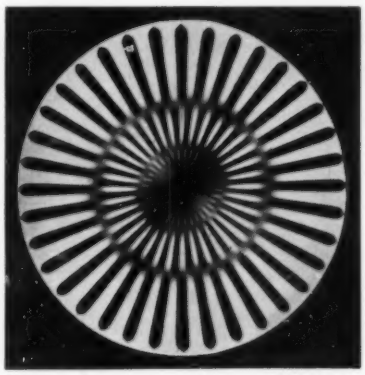

Fig. 22. Pie chart of Fig. 15B photographed with lens at a focal position giving the characteristics shown in Fig. 23. (Lamberts, after Lindberg.)

Speaking generally, the oscillatory nature of the response curve that leads to spurious resolution arises from the flatness of the top of the spread function. Experimental cases have been cited[28,59] in which a lens has been arranged to produce a practically crenelate spread function, and the phenomena just described have been observed. For example, a photographic lens that produces an excellent image in its plane of best focus was displaced 0.6 mm from this plane and the pie chart shown in Fig. 15B was photographed. The resulting print is shown in Fig. 22. Two rings of spurious resolution are clearly visible, and between these rings is a ring in which resolution is normal again. The spread function of the lens as used is shown in Fig. 23 at the left, and it is evidently about as nearly crenelate as could be expected in practice. The response function is shown at the right, and the similarity to the theoretical function shown in Fig. 21 is evident.

At the opposite extreme from the flat-topped function of Fig. 23 is the pointed

exponential function, which may be written (neglecting certain constants that are immaterial to the present argument)

$$A(\xi) = e^{-\xi}. \tag{21}$$

Now it has long been known that this function approximately describes the distribution of effective exposure in an emulsion when a film is exposed behind a stop containing a very narrow slit in contact with the emulsion.[60,61] The sine-wave response corresponding to such a distribution has the form

$$A(\nu) = (1 + \nu^2)^{-1}. \tag{22}$$

A better approximation[62] to the effective exposure can be made by combining Eq. (21) with an equation having the form

$$A(\xi) = e^{-\xi^2}. \tag{23}$$

This will be recognized as the form of the normal or Gaussian distribution function, which, as mentioned earlier, often approximates actual spread functions. The Fourier transform of such a function is of the type

$$A(\nu) = e^{-\nu^2}. \tag{24}$$

Both this equation and Eq. (22) start at unity for $\nu = 0$ and drop asymptotically to the horizontal axis for $\nu = \infty$ without the oscillations exhibited by the curve in Fig. 21. Since the spread functions from which these transforms were obtained together describe the spread function in a photographic emulsion, it may be concluded that a photographic emulsion by itself will not introduce spurious resolution. On the other hand, the spread function of a lens may take any of a multitude of forms, and therefore spurious resolution must be constantly guarded against when lenses are being appraised. In general, the broader the top of the spread function, the more likely the sine-wave response is to have a tail that becomes periodically negative; the more sweeping the toe of the spread function, the more likely the sine-wave response is to have a sweeping tail that is everywhere positive. A set of spread functions that can be described by simple formulas has been published[63] with their corresponding sine-wave responses, and they illustrate this principle.

11. Comparison of Methods

The spread function, the sine-wave response (with phase data when necessary), and the edge trace are interconvertible and to that extent are equally valid for appraising the quality of an optical or a photographic system. Nevertheless, they are not equally suitable in any given situation from the standpoint of convenience, precision, or ease of visualization.

The spread function of a lens is easy to compute from the design data, and indeed the spot diagram itself gives a very good picture of this function.

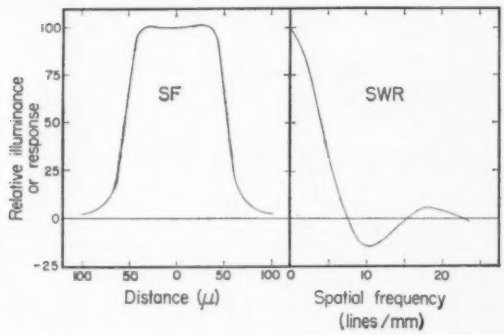

Fig. 23. Spread function (SF) and sine-wave response (SWR) of lens used to make Fig. 22.

These spot diagrams can be analyzed into what may be considered the spread functions corresponding to individual aberrations, and this helps the lens designer to improve his formula.[64] Moreover, lens designers have long been accustomed to evaluating their products by studying the image of a point object, and the distribution of light within this image is by definition the spread function. Nevertheless, deductions drawn from the spot diagrams or the spread function are not unequivocal. When the image is large, there is no doubt but that diminishing its size results in an improvement, but when it is small, its shape begins to be of chief importance, as was shown in Section 9. As was pointed out in Section 5 (Part I), the spread function can be characterized by a single number representing the diameter of the circle within which a given fraction of the light is concentrated, but such a figure cannot indicate the shape of the spread function and it ceases to have much significance when the image is markedly longer in one direction than in the other. Then, too, the spread functions of the individual elements of a system can be combined only by a tedious process of convolution and they are difficult to evaluate by direct experimental methods. The precision is also low when the emulsion spread-function is determined directly because all the results depend on a very small image that is highly localized on the emulsion, and a slight error in evaluating the image or a slight lack of homogeneity in the emulsion or nonuniformity of processing will vitiate the results seriously.

Of the three methods, the sine-wave response is least likely to be vitiated by a slight experimental error and, in the case of emulsions, it gives results that are fairly representative of the emulsion. Considerable time is required to determine it by the conceptually simple method described in Section 8, but the necessary time is reduced to a practical magnitude by the more sophisticated methods described in the references. When the responses of the elements of a system are known, the overall response can be computed by simply multiplying the individual responses together, ordinate by ordinate. On the other hand, it is difficult for an unpracticed person to visualize the spread function from the response curves. Moreover, to reconstitute a spread function that is not rotationally symmetrical, at least two response curves are needed, with phase data for orientations in which the spread function is not bilaterally symmetrical. But certain deductions can be made directly from the sine-wave response. If the response for system A is higher than for system B at low frequencies, system A will reproduce large details more sharply than system B; if the response of system A is higher at the high frequencies, it will distinguishably reproduce finer details than will system B. Here again it would be desirable to characterize the sine-wave response by a single number, such as the cutoff frequency ν_c discussed in Section 7, but this does not take into account the shapes of the response curves.

The edge trace shares with the spread function the advantage of rapid experimental determination and the disadvantage of requiring that broad conclusions be drawn from measurements made on a small image. It is also not an easy source from which to derive the spread function and thence the sine-wave response because, as pointed out in Section 6 (Part I), to do so requires measuring the slope of the edge trace at successive points, and measurements of slope are difficult to make accurately. The edge trace is also even less readily interpreted analytically than the spread function. Moreover, just as for the spread function, if the image of a knife-edge is formed on an emulsion with a lens, the modifying effect of the lens must be removed from the overall measurement to give the true characteristics of the emulsion. It might be supposed that this procedure could be avoided by simply laying a physical knife-edge on the emulsion itself, but light diffused backwards from the emulsion is reflected at the lower surface of the knife-edge into the emulsion again so that, from the standpoint of incident exposure, the knife-edge is actually unsharp. The idea of blackening the surface of the knife-edge that presses against the sample comes to mind, but the experience of the writer is that this is inadequate. A black coating that

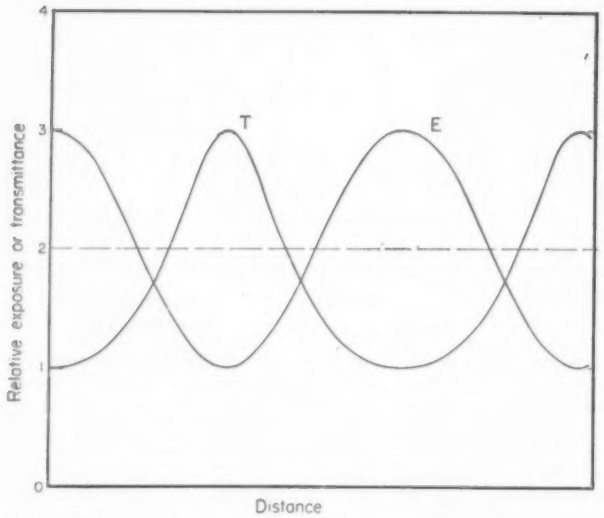

Fig. 24. Graphs showing distortion of sinusoidal exposure pattern by a photographic material used within the linear part of the *D*-log *E* curve. *E*, exposure pattern of 50% modulation; *T*, transmittance pattern of developed negative. Note sharp maxima and gently rounded minima of transmittance pattern.

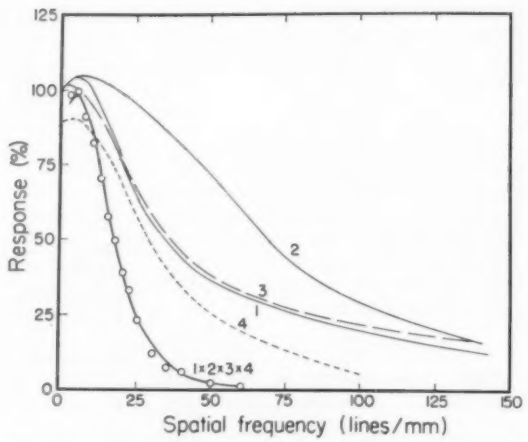

Fig. 25. Sine-wave response curves of four emulsions and their combination. 1, camera negative; 2, duplicating positive; 3, duplicating negative; 4, release positive. Small circles, response of release print made by successive printings; heavy curve, theoretical combined response found by multiplying curves 1–4 together.

would be sufficiently matte to be effective would produce a rough edge and, moreover, the coating would have a tendency to come off on the film. To make the extreme edge sufficiently sharp, it must be polished, and it is the reflection at this extreme edge that causes most of the damage. Moreover, there is a suspicion that diffraction produces an effect even within the short distance represented by the thickness of the emulsion. A possible result of this effective unsharpness of the edge is an apparent asymmetry in the edge trace, and the asymmetry of emulsion spread-functions that have sometimes been reported[65] may be due to this cause. On the other hand, an apparatus[66] for testing lenses that involves a rotating sector disc, the edges of the opaque sectors serving as the knife-edges, has been found to give the same results as more orthodox apparatus.

12. The Overall Response When Printing Is Involved

When every element of a cascaded system is linear — when the output of each element is proportional to the input — the overall response of the system can be computed by simply multiplying the curves for all the elements together, ordinate by ordinate. When, on the other hand, one or more of the elements is nonlinear, the overall response cannot be so simply computed; the nonlinear element introduces harmonics, and a sinusoidal input signal is not reproduced sinusoidally. This circumstance is well known to electronic engineers and is exemplified by the overloading of an audio amplifier. Of course, two nonlinear elements may compensate for each other, but in this case the two elements may be considered together as a single linear element.

The photographic negative is another example of just such a nonlinear element. During the printing operation, the input signal for the positive stock — the exposure — is proportional to the transmittance of the negative. Over the sensibly straight portion of the *D*-log *E* curve of the negative, it is easy to show that the relation between the exposure of the negative film in the camera and the transmittance of the developed negative is

$$T = KE^{-\gamma}.$$

When $\gamma = 1$ this relation represents a hyperbola modified at very low and very high values of *E* by the departure of the *D*-log *E* curve from linearity; it can never represent a truly straight line.

The effect of this hyperbolic relation on the reproduction of a sinusoidal pattern is shown in Fig. 24, where curve *E* represents a sinusoidal pattern having a ratio of 3 : 1 between maximum and minimum and hence a modulation of 1 . 2 or 50%. When a negative of this pattern developed to unit gamma is made on the straight portion of the *D*-log *E* curve, the resulting curve of transmittance, assuming no light diffusion in the negative during exposure, has the shape of curve *T*. The distortion of this curve is quite evident. Nevertheless, when a print is made of this under the similarly ideal conditions of unit gamma and no light diffusion, so that the sine-wave response is constant, it is easy to show that the distortion of the curve shape is exactly neutralized and the transmittance of the resulting print has the sinusoidal form of curve *E*.

This compensation for distortion is subject to the restrictions that the sine-wave response of the positive film must be constant with frequency and that the gamma-product of the positive and the negative films together must equal unity. Curve *T* in Fig. 24 can be analyzed into Fourier components of successively diminishing amplitude and increasing frequency, and if the sine-wave response of the positive film is not constant, these components will be unequally attenuated and therefore the distortion introduced by the hyperbolic characteristic of the negative film will not be exactly compensated for by the corresponding distortion introduced by the characteristic of the positive film. It can be shown[67] that the distortion of the negative diminishes with decreasing exposure modulation and decreasing gamma of the negative, but of course there are practical lower limits to exposure modulation and negative gamma.

The requirement that the positive material should have as constant a sine-wave response as possible does not mean that a positive material with a rapidly dropping response cannot be cascaded mathematically to give the overall response of the photographic process in which it forms a part. It is true that the addition or elimination of harmonics affects the shape of the wave (that is, it introduces distortion). But the modulation of the transmittance curve is determined only by the amplitude of the curve and not by its shape. The presence or absence of the harmonics may affect the distortion markedly, but they form such a minute fraction of the total that their elimination by the frequency-filtering action of the positive film affects the modulation only slightly.

The accuracy with which the simple

cascading process gives the overall response function of a print is shown[67] by Fig. 25. The curves in numerical order are the response functions of the camera negative, the duplicating positive, the duplicating negative and the theater release print. When these are multiplied together, they give the lowest curve, which is the theoretical overall response for the original exposure plus the three successive printings. The actual printing operations were carried out by contact in a vacuum frame with a point source of light, and the response as determined from the microphotometer trace is shown by the small circles. The modulation of the original exposure was less than 68%. It is clear that the overall response can be predicted for a cascade of even three printing operations if these operations are conducted so that additional diffusion is not introduced from such extraneous sources as poor contact.

A similar procedure can be used to determine whether the printing conditions are as good as possible. The solid curve in Fig. 26 is the theoretical overall response for a certain theater-release positive film printed from a camera negative film. The response obtained when a negative was made of a sinusoidal test object and printed on the positive film with a commercial motion-picture printer is indicated by the triangles. This response is obviously very inferior and would lead to a loss of the fine details in the picture and of the high frequencies in the soundtrack. When the negative was printed in the printer described in the preceding paragraph, the response indicated by the small circles was obtained, and it is clear that no improvement over this is to be expected but that it is theoretically possible to make a notable improvement in the performance of the commercial printer.

It has been possible to give here only an outline of the newer concepts involved in the appraisal of optical and photographic systems and a slight idea of their capabilities. These concepts are giving us a much deeper insight into the behavior of such systems, and papers based upon them are constantly appearing.[68] It may not be long before the practical photographer will be as familiar with spread functions and sine-wave response as he is today with graininess and resolving power.

APPENDIX

Computation of Sine-Wave Response From Spread Function

Experimental methods of determining the sine-wave response of a lens have been described in the text. From a mathematical standpoint, they consist in convoluting the spread function with a series of sinusoidal object functions. The same thing can be done by computation, but to see how this is done, additional formulas must be developed.

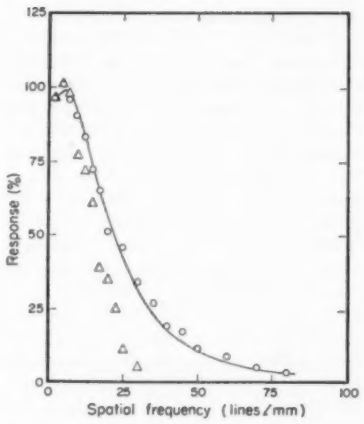

Fig. 26. Test of quality of printing operation. △, sine-wave response of print made with commercial motion-picture printer; ○, response of print made in vacuum frame; curve, theoretical response computed from responses of negative and positive stocks.

In Section 8 it was shown that the light distribution in the image of a sinusoidal object could be expressed as

$$F(x) = b_0 + b_1 A^{\phi c} \cos 2\pi\nu x + b_1 A^{\phi s} \sin 2\pi\nu x, \quad (15')$$

where $A^{\phi c}$ and $A^{\phi s}$ are the cosine and the sine Fourier transforms of the spread function, respectively. They are, of course, functions of frequency, and for any given frequency the cosine transform can be written

$$A^{\phi c}(\nu) = \frac{\int_{-\infty}^{\infty} A(\xi) \cos 2\pi\nu\xi \, d\xi}{\int_{-\infty}^{\infty} A(\xi) d\xi} \quad (25)$$

and the sine transform can be expressed analogously. Here the quantity ξ is measured along the axis but its origin is at the center of the spread function, as shown in Fig. 27. The denominator is simply the area of the spread function alone and is introduced to normalize the expression. Since the modulus of the Fourier transform is related to the cosine and sine components of the transform by the equation

$$|A^{\phi}| = (A^{\phi c 2} + A^{\phi s 2})^{\frac{1}{2}}, \quad (16')$$

it can be readily computed when the cosine and sine transforms are known.

The practical way of evaluating these transforms is to follow the procedure indicated by Fig. 27. The origin of abscissas is taken at some convenient point of the spread function and a maximum of the cosine curve is also placed there. The axis of abscissas is divided into small uniform increments at $\xi_1, \xi_2, \ldots \xi_i \ldots \xi_n$ as shown and the corresponding values of the function $\cos 2\pi\nu\xi_i$ are taken off at each point ξ_i. The equation corresponding to Eq. (25) for this sort of step-by-step summation is

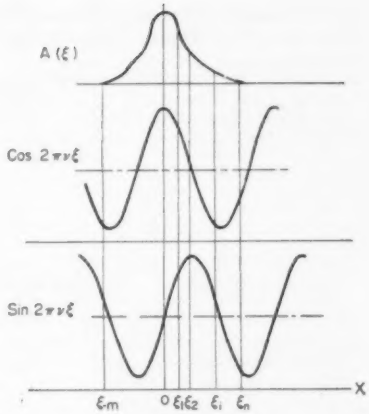

Figure 27

$$A^{\phi c}(\nu) = \frac{\sum_{i=-m}^{n} A(\xi_i) \cos 2\pi\nu\xi_i \, \Delta\xi_i}{\sum_{i=-m}^{n} A(\xi_i)\Delta\xi_i}, \quad (26)$$

where i ranges from the first measurable value $-m$ of the spread function on one side to the smallest measurable value n on the other. First the value $A(\xi_0)$ at the origin is found and multiplied by the corresponding value of $\cos 2\pi\nu\xi_0$ (which is unity here). The same thing is done at every other point ξ_1, ξ_2, etc., from $-m$ to n, and all the products are added together. This gives the value of the numerator for the selected frequency. The denominator is obtained similarly except that the $A(\xi_i)$ are not multiplied by $\cos 2\pi\nu\xi_i$. The process is then repeated for successively higher frequencies (except that the denominator need be computed only once) until a frequency is reached for which the sum becomes negligible. This gives the cosine transform $A^{\phi c}$.

The sine transform $A^{\phi s}$ is obtained in exactly the same way, by combining $A(\xi_i)$ in Fig. 27 with $\sin 2\pi\nu\xi_i$. In this case, for $\xi = 0$, $\sin 2\pi\nu\xi_0 = 0$. If the spread function $A(\xi)$ is symmetrical, it will be found that the sine transform is zero for every frequency because the negative terms in Eq. (27) exactly cancel the positive terms. This means that $A^{\phi c} = |A^{\phi}|$ or the cosine transform alone equals the sine-wave response. Curve F in Fig. 10 was computed in this way from the symmetrical spread function $A(\xi)$ shown at A and the sinusoidal object functions $G(x)$ shown by curves B–E. As is customary, the response values were normalized and therefore the value of curve F at $\nu = 0$ is unity.

Since the transforms $|A^{\phi}|$, $A^{\phi c}$, and $A^{\phi s}$ can be regarded as vectors, we can write

$$A^{\phi c} = |A^{\phi}| \cos \phi, \quad (17')$$

where the argument ϕ is the angle between $A^{\phi s}$ and $|A^{\phi}|$ or the phase

Table I. Numerical Example of Computation of Sine-Wave Response From Spread Function.

ξ (μ)	1 Rel. $A(\xi)$	2 cos $2\pi\nu\xi$	3 (1)×(2)	4 sin $2\pi\nu\xi$	5 (1)×(4)
−7.5	0	−0.71	0	0.71	0
−6.0	0.15	−1.00	−0.15	0	0
−4.5	0.60	−0.71	−0.43	−0.71	−0.43
−3.0	1.00	0	0	−1.00	−1.00
−1.5	1.25	0.71	0.89	−0.71	−0.89
0	1.60	1.00	1.60	0.	0.
1.5	1.80	0.71	1.28	0.71	1.28
3.0	0.50	0	0	1.00	0.50
4.5	0	−0.71	0	0.71	0
Σ	6.90		3.19		−0.54

$A^{\phi c} = 3.19/6.90 = 0.462$

$A^{\phi s} = -0.54/6.90 = -0.078$

$|A^{\phi}| = (0.213 + 0.006)^{\frac{1}{2}} = 0.469$

$\tan\phi = -0.078/0.462 = -0.169$

$\phi = -9°36'$

angle. When $A^{\phi c} = |A^{\phi}|$, it appears from Eq. (17) that $\cos\phi$ must equal unity and therefore $\phi = 0$. This proves that the phase angle is always zero when the spread function is symmetrical, as was stated in the text. Sometimes a more precise value of ξ can be obtained by using the formula

$$\tan\xi = A^{\phi s}/A^{\phi c}. \qquad (27)$$

The procedure can be understood more readily from the numerical example given in Table I. The argument of this table is the distance coordinate ξ, and column 1 is the corresponding ordinate of the spread function $A(\xi)$. Column 2 is the cosine-weighting factor and column 3 is the product of columns 1 and 2. Column 4 is the sine-weighting factor and column 5 is the product of columns 1 and 4. The operation can be followed readily by reference to Eqs. (26), (16) and (27) in turn. The numerical value of the quantity $\Delta\xi_i$ is, of course, 1.5 μ, but this has been ignored in the computations because it cancels out from the numerator and denominator. Somewhat higher precision might have been gained by using a smaller interval, but that is unnecessary for an example and would have lengthened the table. One cycle of the sinusoidal wave used for the transform represents 12.0 μ, and hence the corresponding spatial frequency is 1000/12.0 = 83 cycles/mm. To get the complete response curve, the operation would be repeated for a graded series of frequencies. The curve of phase angle ϕ *versus* frequency ν would be extrapolated back to $\nu = 0$, and then the curve would be moved bodily along the ν-axis to make $\phi = 0$ at $\nu = 0$ because the image must be in phase with the object when the frequency is zero.

The operations involved in the procedure just described are repetitive and are therefore admirably suited for electronic computers. Nevertheless, picking off successive values of the spread function is a considerable chore and is readily susceptible to error. To increase the speed of computation and reduce the likelihood of error, an analog computer has been devised that performs the integration represented by Eq. (25) directly.[69] A scanning device like the one shown in Fig. 13 is set up with a slit instead of the sinusoidal test object so that the spread function of the lens is scanned. The amplified output of the phototube is passed through a rotary potentiometer that has a sinusoidal taper. The speed of rotation of the potentiometer arm relative to the scanning speed is determined by the frequency for which the evaluation is being made. The output of the phototube is thus weighted sinusoidally by the potentiometer to give $A(\xi)\cos 2\pi\nu\xi$ and then it is fed into an integrating device, such as a motor whose speed is proportional to its input voltage and which is connected to a revolution counter. The sine transform is similarly obtained by repeating the scan with the arm of the potentiometer displaced by 90°.

Acknowledgment

The writer is indebted to his colleagues, some of whom have done some of the work described here, for criticism that has led to improvements in the content of this paper and clarification of the expression.

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As this manuscript was being prepared for the press, the fifth meeting of the International Commission on Optics was in session in Stockholm. Many of the papers were on the appraisal of optical systems, and they are being published in *Optica Acta*.

Modern Control of Theater Sound

By GEORGE B. GOODALL

Feature films are now going into theater release with three different soundtrack classifications — single-channel optical, 4-channel magnetic and 6-channel magnetic. When appropriate theater reproducer systems are installed piecemeal, the resulting combination of equipment and controls is often difficult to operate and confusing to the projectionist. A sound reproducing system has been designed to eliminate duplication of controls, simplify routine operating, as well as provide emergency procedures and pushbutton selection of operating modes at each projector position.

MAGNETIC SOUND was introduced to the motion-picture industry a few years ago; it then represented perhaps the first serious attempt to introduce stereophonic sound to the general public.

The first demand for stereophonic reproducing equipment was so sudden that there was little time to think about such niceties as convenience of operation, or even convenience of installation, so the magnetic systems were not combined with the existing single-channel optical systems. (At the time this did not seem too important, because the feeling throughout the industry was that optical sound would soon disappear. This has not been the case.) Some magnetic systems did not even integrate the stage and surround speaker controls.

The projectionist was then, with few exceptions, confronted by an awesome array of controls and equipment to handle only one aspect — the sound — of the multiple responsibilities of his position.

This is no exaggeration. Figure 1 shows the controls on the front wall of a typical projection room equipped to run 4-channel magnetic and single-channel optical soundtracks (plus intermission programing). Only two operations concerned with sound are normally necessary during a performance — the changeover between projectors and the adjustment of level in the auditorium. The duplication of controls to handle identical functions has resulted in ten different controls to accomplish two operations.

Starting with a very few theaters approximately four years ago, more and more houses are being converted to a long-run, road-show policy. The feature pictures intended for these theaters use 70mm film with 6-channel magnetic sound. It has become apparent that we can no longer modify and expand; we must integrate the reproducing equipment into one system which eliminates duplicate and triplicate controls.

Original Design Goals

Certain objectives were originally set up as design goals. Most important was the need for universal controls to operate identical functions, common to every type of sound. This applied particularly to changeover, auditorium level and emergency controls.

It was decided that emergency procedures would allow complete reproduction of the recording, without sacrificing one channel in favor of another. (It is quite common to sacrifice the "surround" channel to continue full-stage speaker output during emergency operation.)

The system had to be capable of selecting not only the six soundtracks on the road-show releases, but also 4-channel magnetic and single-channel optical tracks. Some of the road show films would have synchronous sound, where the magnetic tracks would be recorded on film separate from the picture film, so a selection for this sound was necessary. A fifth selector would allow the programing of intermission (nonsynchronous) music through the normal system.

A practical aspect of motion-picture production is that the changeover point must be determined by the *picture*, with sound a minor consideration. Road-show releases have almost continuous background music or sound effects, which means that the changeover practically never occurs during a period of silence. It was thus necessary that the new system avoid relay-controlled sound changeover, with associated muting circuits.

The main design goal was a unified installation, appropriate to the convenience of the projectionist.

Results of the Design Program

Two systems were designed, one employing "high-level" switching and the other "low-level" switching. These designations describe the point in the circuit where sound selection and sound changeover are controlled. In the low-level system, leads from the magnetic heads are switched, and seven preamplifiers, plus the sensing unit, suffice for the system. In the high-level switch-

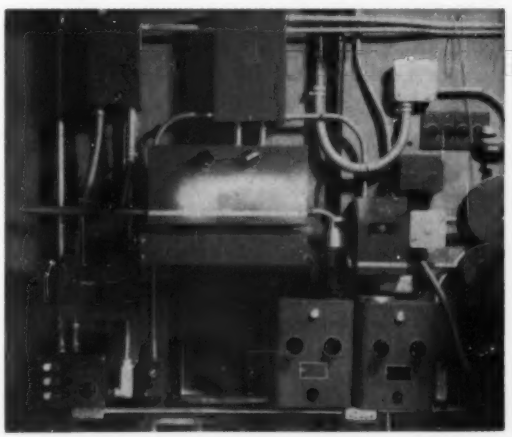

Fig. 1. Controls for 4-channel magnetic and single-channel optical soundtracks.

Presented on October 5, 1959, at the Society's Convention in New York by George B. Goodall, Professional Products Div., Ampex Corp., 934 Charter St., Redwood City, Calif.
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Fig. 2. Station control box for 70mm and 35mm productions.

Fig. 3. Equipment in front-opening racks.

ing system, the controls are applied after preamplification, thus each projector must be supplied with a separate preamplifier for each channel in all three configurations of soundtracks. A normal three-projector installation, where synchronous sound from a separate magnetic sound film is unnecessary, will require 30 magnetic preamplifiers, plus three 12-kc sensing units. (In CinemaScope pictures, the surround channel is operative only when a 12-kc tone actuates the sensing unit.) We shall examine only the high-level switching system in this discussion.

One result of the design and development program is indicated in Fig. 2. This photograph was taken in a theater recently converted to a road-show basis, at a position corresponding to that of Fig. 1. Despite the fact that this projection room is equipped to run two more types of soundtracks than the first, the single small control box in the upper center of the picture provides complete and instantaneous sound selection, sound changeover, and auditorium level control.

One of these control units for each projector, and the master gain control, are mounted on the front wall of the projection room. All other equipment is mounted in front-opening cabinet racks (Fig. 3) which can be located at any convenient point near the projectors.

Functional Description of Complete System

A simplified functional block diagram of the complete system is shown in Fig. 4. Any number of projectors can be employed, each requiring a separate bank of preamplifiers and a separate switch panel. (For reasons of simplicity the connections for synchronous sound have been eliminated from the functional block diagram.)

The audio signals from the magnetic heads, photoelectric cell, or nonsync source proceed directly to the preamplifiers. The inputs of the preamplifiers may be strapped for either low-impedance (40 ohms) or high-impedance (150-250 ohms) heads. It is to be noted that separate preamplifiers are provided for each source, thus each projector will need six for 6-channel synchronous, six for 6-channel composite, four for CinemaScope (plus a 12-kc sensing unit), and one for optical.

From the preamplifiers, whose output impedance is 600 ohms, the signal is routed to the switch panel, controlled by pushbutton switches at each station control box. Any type of soundtrack may be instantly selected by pressing the appropriate button. A sound changeover pushbutton at each station unit controls a changeover switch on the switch panel, determining which projector will originate the signal to the system. Next in the circuit is the master gain control unit, consisting of six ganged, 600-ohm attenuators. This control is mechanically coupled to each station control unit so that local regulation of auditorium sound level can be accomplished at each projector.

The signal then proceeds to the monitor and emergency panel. This panel provides switching across the seven power amplifiers, whose input bridges the 600-ohm line and which may be strapped for 8-, 16- or 32-ohm output (or 70-v line). Power amplifiers 6 and 7 are normally paralleled to drive the surround speakers, with 1 through 5 driving the five-stage speakers.

The monitor selector switch allows the projectionist to monitor all channels simultaneously or each channel individually. A test jack, the signal at which is also selected by the monitor switch, provides a convenient point to check signal level with a voltmeter; an *off-test* position of the amplifier switch terminates each amplifier in a resistive load for testing and adjusting under identical conditions.

From the monitor and emergency panel the signal is routed to the loudspeaker system.

Equalization

All equalization is provided in the preamplifiers, with plug-in circuits utilized. Six-channel soundtracks use the same reproduce curve as the standard four-channel, so identical equalization is used in all magnetic preamplifiers. Optical equalization, following the Motion Picture Research Council recommended curve, may be obtained by either using a plug-in optical equalizer in the preamplifier, or by employing a photoelectric cell coupling unit working into a normal magnetic preamplifier. The coupling unit converts the output characteristics of a photoelectric cell to coincide with those of a magnetic head, and this method results in having all preamplifiers of a standard configuration.

Sound Selection Circuit

Sound selection is controlled by the five pushbuttons mounted in a row

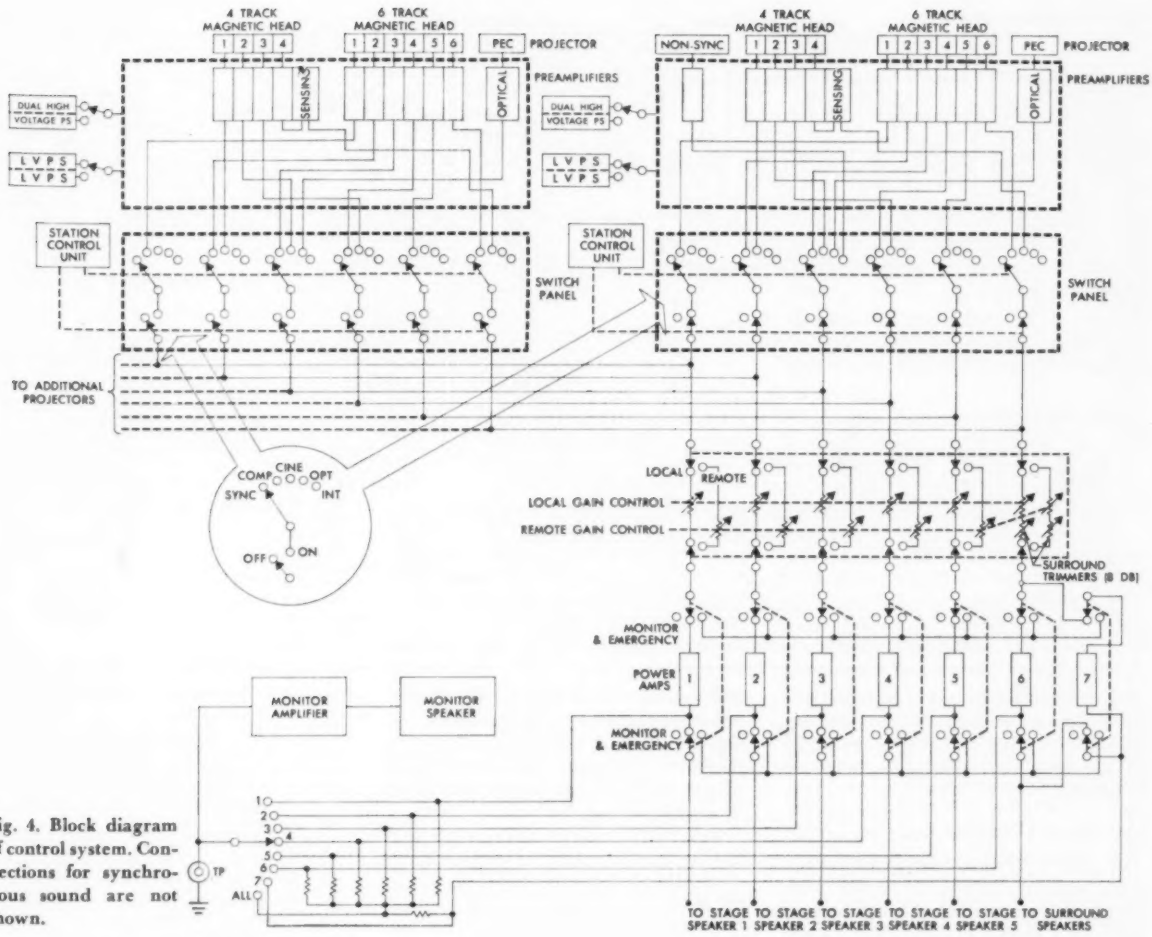


Fig. 4. Block diagram of control system. Connections for synchronous sound are not shown.

across the station unit (Fig. 5). These buttons control the action of a rotary stepping mechanism on a switching panel in the racked equipment. Each station unit controls the sound selection at the adjacent projector only, so one projector can be running one type of soundtrack while the other is set up for a different type.

The rotary stepping action mechanically controls the positioning of a seven-deck switch, one for each of six channels plus a pilot light deck (Fig. 6). Lights on the control unit visually indicate the sound selection. An 80-v power supply provides d-c power for the rotary switch and the changeover switch.

Sound Changeover Circuit

Changeover of sound between projectors is accomplished by one pushbutton at each station unit (Fig. 5). As this button is pressed, sound originating from the adjacent projector is connected in the circuit and that from all other projectors is discontinued. Two rotary-type solenoids are employed at each switching panel — one *on* coil and one *off* coil (Fig. 6). The pushbutton at each station simultaneously actuates

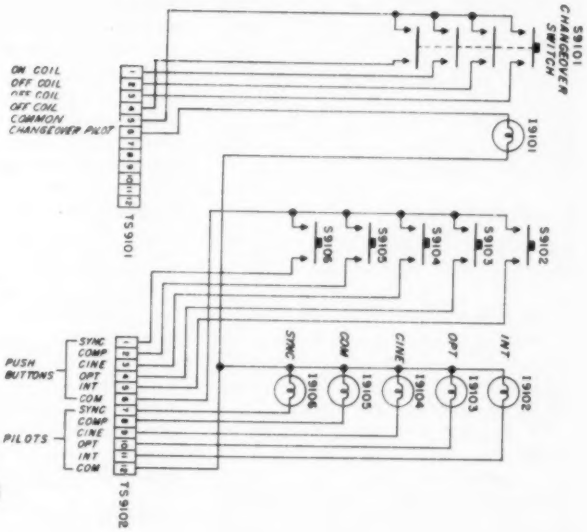
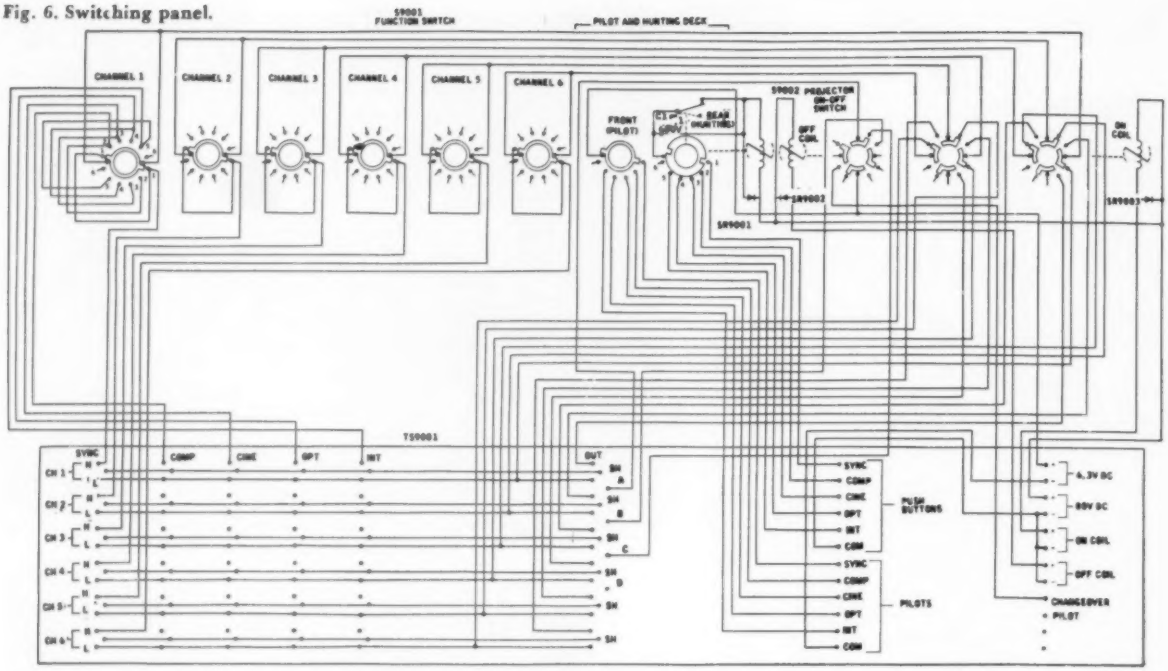


Fig. 5. Station control unit.

the *on* coil for the adjacent projector and the *off* coil for all other projectors. The rotary solenoids are mechanically coupled to a double-throw, three-deck switch. As the *on* solenoid at any projector is actuated it causes the switch to move in a direction that removes a short from the sound circuit of that projector. At the same time the *off* solenoids of all other switching panels are actuated; those switches close, and sound originating from other projectors is shorted out.

Instantaneous and noiseless change-

Fig. 6. Switching panel.



over is achieved by using high-quality, silver contact switches in this circuit, and by the precise routing and cabling of all leads. No muting devices are required.

Level Control Configuration

A rigid mechanical coupling extends from the master gain panel through each station unit to provide auditorium level control at each projector. The master gain adjusts the sound level of all channels simultaneously, with an additional 8-db trimmer control for the surround channel. Provision is made to transfer sound control to a remote location in the auditorium, so that this function can, when desired, be adjusted by someone sitting in the audience.

Emergency Facilities

All power supplies are provided in duplicate, with appropriate switching to insert the standby supplies in the circuit if the normal unit fails. Plug-in magnetic preamplifiers are always available, as at least ten are supplied for each projector and not more than six will be in use at any given time.

The monitor and emergency switches bridge the inputs and outputs of all power amplifiers. It will be recalled that power amplifiers 6 and 7 normally are paralleled to drive the surround speakers. If a stage channel amplifier fails it is necessary only to change the switch for that channel and for channel 7 to the emergency positions. This action substitutes amplifier 7 for the faulty amplifier, and full stereophonic operation continues — with amplifier 6 still driving the surround speakers. The surround level trimmer control can now be adjusted to compensate for any loss in surround volume. The input of the faulty amplifier will automatically be shorted, and its output terminated in a resistive load.

Insertion losses to the surround speakers usually require that the output levels of amplifiers 6 and 7 be higher than those for the stage channels. Thus, if amplifier 7 were substituted in a stage channel it would cause an unbalanced condition with one channel louder than the other four. A potentiometer has, therefore, been inserted in the emergency input to this power amplifier to achieve an emergency output level preset to equal that of the stage channels. This control is adjusted during installation.

Conclusion

The sound system described has been installed in many road-show theaters throughout the country. Its advantages include simple operation, complete emergency facilities, and compact installation characteristics. Perhaps its greatest contribution is in the elimination of duplicate and triplicate operating and emergency controls; in this respect it represents an advanced approach to the control of theater sound.

Acknowledgment

Credit for originating and developing the selection and control system is due H. G. Hummel and E. M. Lewis of Ampex Corp.

Discussion

Edgar A. Schuller (*DeLuxe Labs., New York*): I'd like to know what kind of survey of theater installations you made before you decided to develop this equipment.

Mr. Goodall: The company went to the exhibitors, the producers and the projectionists themselves to find out what the projectionist needed, what the exhibitor thought he could pay, and what the producers were going to use. Does that answer your question?

Mr. Schuller: How extensive was that survey?

Mr. Goodall: I feel it was quite extensive. Mr. Lewis is here in the audience. He is one of the instigators of the system, perhaps he can answer it better than I can.

E. M. Lewis (*Ampex Corp., Redwood City, Calif.*): We concentrated our technical investigation in the Hollywood area, contacting many of the outstanding directors, sound engineers and projectionists. Our marketing department mailed questionnaires to representative theaters and projectionists throughout the country. A prototype system was used with the first picture — *Oklahoma* — at the Egyptian Theater in Hollywood.

Mr. Schuller: Then I would assume that it was a pretty representative survey. Did you find that some theaters were using CinemaScope film with magnetic tracks and reproducing only one channel?

Mr. Goodall: I think that has occurred, yes. And they do have a lot of films where they have a choice (in the mag-optical prints) between 4-channel magnetic and optical. Some of them were using the optical.

Mr. Schuller: Yes, it's unfortunate, but it's a fact. I notice that on your selector switch you have one position marked "Todd-A-O Synchronous" and another "Todd-A-O Composite." What is the difference?

Mr. Goodall: "Synchronous" means the sound is recorded separately from the picture film and a film transport or some similar device would be used that would have to run in synchronism with the projector. A "Composite" picture is, of course, one with the sound recorded on the same film as the picture.

Mr. Schuller: I wasn't aware of the fact that Todd-A-O was also released in the double-system format.

Mr. Goodall: This was done right at the start of the Todd-A-O productions. I don't know if there are any future plans for such productions, but of course we had to make allowances for it.

New Technology in Lighting Control Equipment

By WALTER A. LEVY

Two recent innovations in lighting control equipment, the silicon controlled rectifier dimmer and the "infinite preset" control system, offer new and exciting possibilities in the field of studio lighting. These innovations have raised interesting technical problems which are discussed.

TWO NOTABLE DEVELOPMENTS have been introduced recently by the theatrical lighting industry; the use of the silicon controlled rectifier (S.C.R.) as a dimmer component and the use of punch-card equipment for "infinite preset" systems. As both these developments involve technology new to the industry, it is difficult to discuss them without first defining standards for evaluation which, while based upon lighting industry requirements, are consistent with experience in the semiconductor and data-processing industries.

The operational features of these two developments have been adequately described by the various equipment manufacturers and are not the subject of this paper.* It is, however, intended to discuss reliability, definition of performance, and maintainability aspects of the use of these new techniques in lighting control applications. It is hoped that this discussion will help establish standards for evaluation of these essential, but "nonoperational" aspects of the new developments.

The Silicon Controlled Rectifier Dimmer†

It is, by now, common knowledge that the most important engineering problem in the use of the silicon controlled rectifier in a dimmer is the problem of protection. There are two basic reasons for the importance of this problem:

(1) Semiconductor devices are much less capable of withstanding relatively moderate or short-duration overloads than any other power control device.

(2) The commercially available S.C.R. dimmers are using the S.C.R. very close to its maximum ratings.

As the object of protection is to keep a device from being operated beyond its ratings, there are three significant ratings of the S.C.R. which must be examined in detail:

(*1*) *Steady-State Full-Load Current Rating.* The full-load current rating is established to prevent the S.C.R. from overheating and destroying itself. This is essentially a heat transfer problem in which the temperature of the air surrounding the S.C.R. is a very significant factor. The operating temperature of the S.C.R. in presently available dimmers is sufficiently close to the maximum allowable to cause concern that high, but not abnormal, equipment temperature may induce failure of the S.C.R. The use of a thermal overload breaker mounted in the dimmer chassis is clearly desirable for protection. Ventilation of the equipment must be carefully designed because of the need for close control over temperature. The idea of mounting an S.C.R. dimmer in close proximity to the spotlight it controls should be approached with the utmost caution because of this temperature problem.

(*2*) *Surge Current Rating.* The S.C.R. is very limited in its ability to avoid destruction due to the high inrush current drawn by a cold incandescent lamp. The present ratings for surge capacity signify the S.C.R.'s ability to withstand accidental surges but not repeated surges that are part of the normal operation of the application. Because the S.C.R. is such a new device, evidence has not yet been accumulated which permits a precise definition of the "operational surge current ratings." There is little doubt, however, that the closer the repeated surges may approach the rating established for accidental surges, the greater is the probability for failure of the S.C.R.

There are two methods currently known for surge protection: (1) the high-speed current-limiting fuse (amp trap) and (2) the current limiting reactor. Either method may be designed for any desired safety margin below the "accidental surge" rating of the S.C.R. If the method of protection is the amp trap, there is a trade-off between the safety margin against surges and the dimmer capacity. Use of the current limiting reactor may cause a problem in dimmer voltage regulation but otherwise does not require a trade-off of dimmer capacity against safety margin.

(*3*) *Peak Inverse Voltage Rating.* If the applied peak voltage exceeds the peak inverse voltage (PIV) rating of the S.C.R. for more than a few milliseconds, the cell may be damaged. The rating of the G.E. C 35B S.C.R. currently used is 200 v. In the conventional back-to-back dimmer circuit the applied PIV is 1.414 × (line voltage). Thus the PIV applied by a 120-v line is 170 v and if the line is boosted to (say) 130 v to compensate for dimmer losses, the peak voltage is 184 v. The application thus will utilize 85% to 92% of the rating. The risk involved here lies in the possibility of transient voltages induced on the power lines feeding an S.C.R. dimmer installation being sufficient in magnitude and duration to cause a failure. It is unfortunately very difficult to evaluate this risk, as no device hitherto used in common 120-v lighting systems has been nearly as sensitive to voltage transients and consequently able to offer a history for examination.

An S.C.R. manufacturer's PIV rating must be very precise. A clue to the precision of this rating is the fact that the PIV rating of the next higher rated cell (Model C35H) is only 250 v and the price goes up in direct proportion to the PIV rating.

These facts about PIV rating are not offered to cause alarm, but only to illustrate some basic problems in the application of semiconductor devices. With regard to voltage ratings, we may state that: (a) due to a phenomenon known as "avalanche breakdown," the PIV rating of any semiconductor device is quite precise, and must be carefully regarded; and (b) high PIV ratings are inherently difficult to achieve in semiconductor devices and therefore a very costly property. (The ability of the S.C.R. to control power at high voltages constitutes a major breakthrough in the art.)

As a result of these two basic facts, it is common practice in transistor circuit design to determine the PIV requirement very carefully but to use the PIV rating of the transistor "to the hilt."

Figures are not offered on interpreta-

A contribution submitted on October 27, 1959, by Walter A. Levy, 160A Haddon Hills, Haddonfield, N.J.

*Rollo Gillespie Williams, "Significant developments in TV studio lighting layouts," *Jour. SMPTE, 68:* 545–547, Aug. 1959; and Herbert W. More and Albert W. Malang, "The silicon controlled rectifier dimmer," *Jour. SMPTE, 68:* 678–683, Oct. 1959. (Both papers were delivered on May 6, 1959, at the Society's Convention in Miami Beach.)

†The term "silicon controlled rectifier dimmer" (abbreviated as S.C.R. dimmer) is used in this paper in a general sense to refer to any dimmer using the silicon controlled rectifier as the power controlling element.

tion of current ratings, because there is some difference in approach by the various equipment manufacturers and the author does not want to compare specific commercial products. (The use of the 200-v PIV rating is common, and the figures offered here permit a comparison between application and rating which is not inconsistent with that which could be made on the interpretation of current ratings.) However, while experience in transistor circuit design indicates that use of PIV rating "to the hilt" is reasonably safe, the experience with regard to current ratings is not the same.

Contrary to the popular impression, semiconductor devices do not possess indefinite life and it has been proven necessary to operate transistors and rectifiers well below maximum current ratings in the particular circuit application if long life is to be assured.

In the application of the S.C.R. one must therefore expect a correspondence to exist between conservative dimmer rating and longevity. What this correspondence will be and what the average lifetime of dimmers of a given rating will be, however, can only be determined from experience.

To summarize this discussion of the ratings and protection of the S.C.R. as it is being used in lighting control, one must make some comparisons between the S.C.R. and the other devices being used as dimmers. These other devices are:

(1) the variable autotransformer dimmer,

(2) the output saturable reactor and blocking rectifier components of the magnetic amplifier dimmer, and

(3) the thyratron tube.

The first two devices have been widely used for years with failures virtually unheard of. A "surge current rating" is totally without significance, and the voltage rating of no concern to the protection of the device. Because both of these devices have been designed to achieve specific load capacities by engineers using the time-tested conservative practices of the transformer industry they have proven quite capable of handling full-rated load with practically no failures.

The thyratron has had a good history of reliability but is definitely a device which must be periodically replaced. Enough experience has been recorded on thyratron dimmer usage to allow an estimation of the average lifetime of these tubes. In a typical theatrical system where all the tubes are energized but not necessarily connected to any specific load for the recorded period of time, it is reasonable to expect an average lifetime of 10,000 hours. It is furthermore established that the period of time with the highest rate of tube failures will be the first 1000 hours of operation, during which the manufacturer's warranty is effective.

The thyratron has ratings which are analogous to those of the S.C.R. The C16J Thyratron (made by Electrons, Inc., and to which these lifetime estimates apply) has been in use for several years in a back-to-back circuit as a 4-kw or 5-kw dimmer. Table I will permit a comparison between the significant ratings of the C35B X510 S.C.R. and the C16J Thyratron, both devices being operated in a 4-kw back-to-back dimmer circuit. The third column in the table contains the conditions imposed upon the two dimmer circuits by a 4-kw incandescent load.

With one exception the data for Table I can be read directly from the manufacturer's data sheets. The assumptions of 120-v input for the S.C.R. dimmer and 150-v input for the thyratron dimmer are consistent with present industry practice. The maximum direct current that the 4-kw load will draw through either of the two devices can be given with slightly more precision but nothing will be proven thereby. It should also be clear that the back-to-back circuit uses two devices (either S.C.R. or thyratron) and that the values given are for one of the pair. While the circuit itself passes alternate current, each of the devices passes current in only one direction.

It is evident from examining Table I that the S.C.R. is being used to its ultimate on every count while the thyratron is "loafing" on every rating except the first. On the assumption that the semiconductor device is inherently more long-lived than the gas discharge tube, one may discount this comparison to some extent, but until substantial experience has been recorded, comparisons such as this one are the only available guide to predicting the life of the S.C.R. dimmer.

Table I. Relative Stress on Thyratron and Silicon Controlled Rectifier by a 4-kw Incandescent Load.

Item	Ratings		Stress from 4-kw incand. load
	Thyratron	S.C.R.	
Max. rated d-c, amp.	16	16	16
PIV, volts . . .	1250	200	212 for tube 170 for S.C.R.
Peak surge current, amp	1000	200	610 for tube 490 for S.C.R.
Max. duration of surge, msec	100	8	8 to 45*
Recurrent peak value of current, amp	160	60	61 for tube 49 for S.C.R.
Max. ambient temperature, F°	167	113†	—

* The value of the surge diminishes after the first half-cycle (8 msec) but is very substantial for at least 2 or 3 cycles. It will generally take at least 10 cycles to diminish to approximately 110% of the steady state current.

† The data sheet for the S.C.R. does not give this figure directly. It is the author's estimate based upon the dimmer passing the full current of a 4-kw load. This estimate may be high.

"Infinite Preset" Systems

The questions that arise in evaluating "infinite preset" systems are of a totally different sort from those that arise in connection with the S.C.R. as a dimmer component. Whereas the dimmer is basically a small device using a new and essential component whose reliability has not yet been proven by experience, the "infinite preset" control console used to control a group of these dimmers is essentially a system whose principal components have probably been used for many years and are well established. So long as the particular infinite preset control console being evaluated utilizes these established components, the principal questions of reliability have to do with system design. While there are many possible ways to use data-processing equipment and techniques in infinite preset systems, the method of interest in this discussion is the use of standard punched-card equipment for the recording and reproduction of lighting cues.

The essential functional elements of a punched-card infinite preset control system may be listed as follows:

(1) an individual rehearsal control for each dimmer;

(2) a means for translating the setting of each of the individual rehearsal controls into a punched-card code;

(3) a card punch which will insert the coded dimmer setting information onto a specific area of the card reserved for each dimmer;

(4) a card reader which can scan the card and distribute the coded dimmer intensity information to an individual memory device for each dimmer; and

(5) a pair of memory devices for each dimmer, either of which can accept the punched-card code and translate it back into a dimmer intensity setting. (Provision of a pair of these devices is essential, as normal operation requires setting up the next cue on one device while the other is being used for the current cue.)

The operation of a system utilizing these functional elements consists of a series of steps whose correspondence to this list should be clear without statement. Use of punched-card equipment results in certain features which are highly desirable in that they permit fast and reliable operation of the system. They are:

(1) the ability to record a large number of rehearsal control settings onto the punched card;

(2) the ability of both card punch and card reader to advance cards automati-

cally through their respective mechanisms without handling;

(3) the ability to duplicate or modify complete cards in a very few seconds;

(4) the ability to shift from one cue to the next in a very few seconds;

(5) The inherent capability for the automatic checking of errors made by either machine or operator; and

(6) the inherent capability designed into the system for recording information with any specified degree of accuracy.

While these two lists have been written specifically to describe a system using punched-card equipment, it should be clear that they are easily modified to cover any type of "infinite preset" system. In the discussion which follows relating to punched-card equipment, no principles have been used which are not generally applicable to any type of equipment; therefore, while this discussion is concerned with the use of punched-card equipment, it should contribute to an understanding of the use of other equipment in infinite preset control systems.

The basic justification for developing infinite preset equipment is to simplify the task of controlling very large lighting systems whose use involves many lighting cues. It is, therefore, logical that the mere ability to put a lighting cue on a card is insufficient if the way in which this must be done is laborious, time-consuming and error-prone. To avoid this self-defeating combination, it is essential to establish minimum performance standards for infinite preset systems regardless of how constructed. The list of six advantages previously mentioned as resulting from the use of punched-card equipment should contribute to such a set of minimum standards.

The first four items in the list describe abilities which are based mainly upon lighting control system requirements. These abilities are readily demonstrable in specific equipment. The last two items, however, are essentially concerned with performance definition and reliability, and require further explanation.

There is a specific inverse relationship between the amount of information that may be punched on a card and the degree of accuracy with which it may be expressed. This relation further depends on the capacity of the card, the code which is used, and the degree of error checking required.

Every step in dimmer intensity to be recorded must be represented by a specific pattern of holes on the card. If we allocate an area containing a specific number of hole positions on the card to each dimmer, then the number of intensity steps we may record will depend on the number of possible hole combinations that may be punched in that area according to a set of rules normally called the "punched-card code."

Both Remington Rand and IBM manufacture punched-card equipment which may be used in this application. The Remington Rand card contains 90 columns, each of which may be used to record the intensity of a dimmer. Each column has six hole positions (or rows). The standard IBM card contains 80 columns, each of which may be used to record the intensity of a dimmer. Each column has 12 rows. Both of these card systems have a standard code which is capable of representing the letters of the alphabet, the digits 0 through 9 and some miscellaneous characters all within one column.

If we adapt either of these two standard business machine codes to the representation of lighting intensity, then use of all the "digits" and "letters" allows a 36-position intensity scale. The IBM code has an important virtue in that the punching pattern can be readily interpreted by visual inspection. This is a valuable property because the operator should be able to determine quickly if he has correctly recorded the lighting cue on the card. This is also true of the Remington Rand code but with less convenience.

Another code which may be used with either type of equipment is the binary code. This code is very efficient and, in this application, offers the best combination of card utilization, number of intensity steps per dimmer, and self-checking capability. The binary code punching can be read directly, but with less convenience than the standard IBM code.

The binary code utilizes all the possible combinations of hole punching in a specified number of hole positions. Each combination of holes signifies an intensity setting. A very simple relation exists between the number of hole positions and the scale sensitivity. Here are three significant sets of values:

Number of Hole Positions	*Scale Sensitivity, Steps*
4	16
5	32
6	64

The choice of the 5-position code with a 32-step scale is practical in the light of present theatrical practice.

We can now compare some of the possibilities for card utilization in the different codes:

Type of Card	*Code*	*No. of Dimmers*	*Scale Sensitivity*
IBM	Std. IBM 12-row	80	36 pos.
IBM	5-pos. binary	160*	32 pos.
R.R.	Std. R.R. 6-row	90	36 pos.
R.R.	5-pos. binary	90	32 pos.

* Obtained by splitting the card into two 6-row fields.

This table shows the maximum possible capacity of the various card-code combinations but other considerations will serve to reduce this capacity. Scene and sequence identification information require space, and checking the accuracy of information punched on the card also requires additional space.

The use of error-checking techniques is firmly founded in the data processing industry. It is an accepted fact that errors will occur: the questions are as to probability of an error, its consequences, and what practical means may be used to detect and correct errors. The requirements for error checking in a lighting control application are in one important sense more stringent than the requirements for error checking in an accounting application: a failure is unrecoverable by subsequent checks. Whereas an accounting machine error can usually be picked up by any one of a number of double-checking procedures, an incorrectly executed lighting cue instantly damages the performance. It is therefore desirable to have error-checking techniques which will report the presence of an error to the operator in time to permit corrective action prior to the execution of the cue.

Some of the possible errors that may occur during operation of punched-card infinite preset equipment are: (a) card punched improperly; (b) card read incorrectly; (c) cards placed in wrong sequence (operator error), and (d) card jam in reader.

Punching and reading errors usually are random and caused by dust on contacts, sticky pins, or an undetected failure in the control circuitry. Card jams are usually attributable to damaged or over-sized cards, or dirt accumulation in the transport mechanism.

A program of error-control for infinite preset systems should give consideration to use of the following list of design techniques and operating procedures, all of which are based on established usage in data-processing systems.

(1) Use of an error-checking code for dimmer intensity recording. This requires use of an additional hole position which is punched, if necessary, to assure that the number of holes punched to represent each dimmer intensity setting is always an even number. This even count is checked in the reader and any error immediately signalled to the operator. (This technique may be readily applied to the 5-position binary code on either IBM or Remington Rand cards as the sixth hole position is available without sacrificing dimmer setting capacity.)

(2) The operator should be able to verify the accuracy of punching each card. If time permits, this may be done by visual examination. If time is important, then the system should be

capable of performing this verification automatically in a very few seconds.

(3) Once the sequence of cues is determined, each card should be punched with a sequence indicating number. When each card is read, this number should be presented to the operator so that he knows that the cards are actually being fed in the correct order.

(4) Operators should use the greatest care in handling cards because physical damage can easily jam equipment.

(5) A manually operated 2-scene standby console should be an integral part of the system. This is a very inexpensive safeguard against a system breakdown during a performance.

(6) Special attention to the cleanliness and maintenance of the equipment is essential.

If the basic operation of the system is to set the next cue into the inactive memory device for each dimmer immediately after energizing the current cue, then the operator will have a few minutes to locate any reported error and decide whether he can clear it and proceed with the infinite preset equipment or whether he must transfer control to the standby console.

These comments on infinite preset systems may be summarized by stating that what has been attempted here is a description of an idealized system. This description has included a definition of the basic functional elements, a list of essential features, an explanation of the system's data-handling capacity, and a statement of the basic techniques for error control and safe operation.

It is hoped that this ideal picture will be useful in evaluating the relative merits of actual systems. It should not, however, be assumed that any actual effort which does not meet all these standards is unsuccessful, as one must always consider the value of a good compromise between ideals and economy.

Conclusion

In concluding this paper, it is necessary to observe that many questions have been raised either directly or by implication, but few answers have been offered. In any effort to establish standards it is first necessary to define what is to be questioned and this is substantially what this paper has attempted to do.

A Wide-Band Television Switching System

By ROBERT S. AHA

A wide-band television switching system has been produced by using standard techniques but incorporating a distribution amplifier that was designed to be used as both an input and an output amplifier capable of a bandwidth of more than 17 mc. The requirements also necessitated the design of a small, very low-capacity relay which is an integral part of the overall system.

THE GENERAL SPECIFICATIONS of the wide-band TV switching system that is described herein required that the necessary amplifiers, relays, control circuitry, power supplies and other parts be contained in relay racks. All video switching was to be done by relays that were remotely controlled from the control panels. The basic principle of control in the switching system was to be different from the standard TV studio methods. Each input of the switcher was to be associated with a separate control panel, that is, all the outputs were to be available by means of pushbuttons on each of the control panels. But it was specified that the electrical interlocking of the control panels should allow one control panel to "take away" the input signal from any other control panel. A tally lighting system was also to be associated with each pushbutton. When any pushbutton on any control panel was pushed, its tally light was to go on, telling the operator that he now had command of that input signal. An additional request was to make it possible to connect all outputs to any one input without degradation beyond that given in the electrical specification.

Presented on October 9, 1959, at the Society's Convention in New York by Robert S. Aha, Tarc Electronics Corp., Westbury, L.I., N.Y.
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Electrical Specifications

The electrical specifications called for were as follows:

(a) The switching system shall accommodate input levels of 1 v and provide an output signal of 1 v.

(b) The bandwidth of the switching system shall be flat to within 1.5 db to 17 mc.

(c) Gain of the overall system shall be adjustable at least over the range of 0.8 to 1.2.

(d) Differential gain at an output level of 1 v shall be less than 10%.

(e) Crosstalk between signals shall be at least 35 db down at 17 mc and decreasing with frequency at the rate of 6 db/octave to at least 60 db down at frequencies below 1.0 mc.

Other specifications of signal impedance, switching transients, switching time, power source, etc., were also given.

Design of Relays

The first design problem encountered was the search for a low-capacity relay with which to do the video switching. Many relays were investigated but none met the requirements of extremely low capacity, small size, construction approaching military standards, tally contacts, etc. Finally a relay was evolved with the help of Lionel B. Cornwell of the Magnadyne Corp. This relay was $1\frac{3}{8}$ in. wide by 2 in. long by $1\frac{5}{8}$ in. high. The total capacity to ground of the form-C video contact with all the form-C contacts tied together was 1.75 $\mu\mu$f. The capacity across the open contacts was 0.8 $\mu\mu$f. Two form-C contacts for tally circuitry were also mounted on the relay. Using this relay as the basis for the video switching function, the design of the overall system was begun.

As shown in Fig. 1, the switching system was divided into the following sections: the input amplifier, the relay switching system with the input bus, the preamplifier and output bus, and the output amplifier.

It was decided that for ease of maintenance, the input and output amplifiers should be plug-in, and if possible, identical except for alignment. Any differences between them such as the output impedance networks should be contained within the housing of the input and output amplifiers.

Crosstalk

Another design problem was the ground or chassis crosstalk problem. With the necessity of using low-impedance terminations for most of the cabling within the switcher, any relatively

high-resistance ground connections or long ground returns would have to be eliminated. This was accomplished through the use of insulated coaxial connectors, that is, insulated from each other with separate ground returns for each low-impedance cable or bus. This technique was also used in the construction of the input and output amplifiers. Crosstalk of these amplifiers even at 17 mc was better than 55 to 60 db down and was not measurable below 8 mc.

Amplifier Stages

As shown in Fig. 2, the in- and output amplifiers consist of three stages: a series compensated pentode amplifier which is d-c coupled to a triode cathode follower, and a hybrid or bootstrap dual triode as the output amplifier. Overall feedback from the output amplifier back to the cathode of the pentode amplifier through a parallel network of fixed resistance and variable capacitance provides for very low output impedance, very good frequency response and good linearity. The high- and mid-frequency responses of this amplifier are controlled by the series compensation coil in the plate circuit of the pentode amplifier and the variable capacity in the feedback network. The gain of the amplifier when it is plugged into the input housing is 2.75. When it is plugged into the output housing, the gain is 2.2.

Precision resistors are used in both the plate circuit of the pentode amplifier and in the feedback and cathode circuit of the pentode amplifier. This was done to enhance the gain stability of the amplifier.

The preamplifier uses a dual triode as a cascaded amplifier. Series peaking in the plate circuit of the first triode and overall feedback contribute to make a very wide-band linear amplifier. The gain in this stage is approximately 3.

Video Distribution System

The video distribution system within the relay area makes use of an input and output bus of a $\frac{3}{16}$-in. by $\frac{3}{16}$-in. aluminum bar of the correct length, and a compensated precision resistance and a capacitance divider.

With an operate-and-release time of the video relays of 7-9 msec and of the holding relays, 3-4 msec, the overlap switching time is approximately 3.5 msec. The crosstalk as a function of the mechanical overlap is more than 46 db down, so that there is no noticeable effect on any input signal when another output bus is connected to it.

Switching System Operation

Operation of the switching system may be explained by means of a simplified drawing of one of the 14 input by 20 output switchers as shown in Fig. 1.

With a video signal of 1 v at the input of the input switcher amplifier and no relays energized except the holding relay

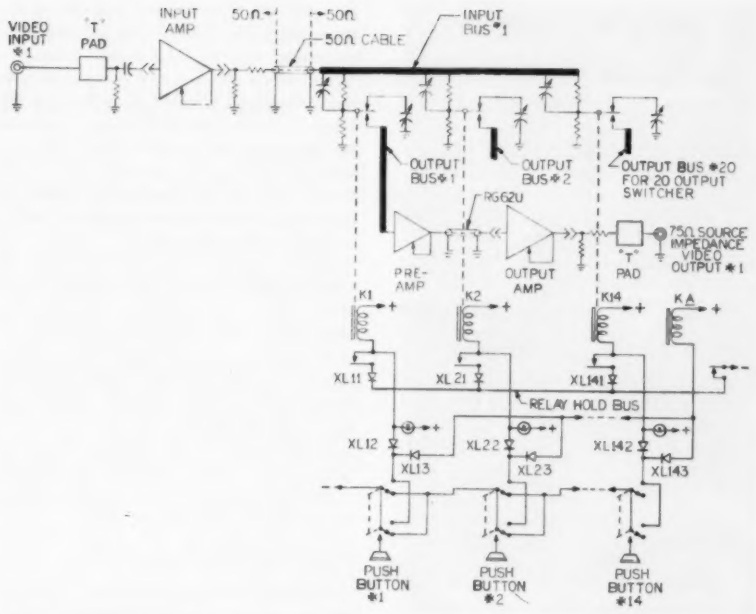

Fig. 1. Block diagram of switcher including pushbutton arrangement for operation of the system.

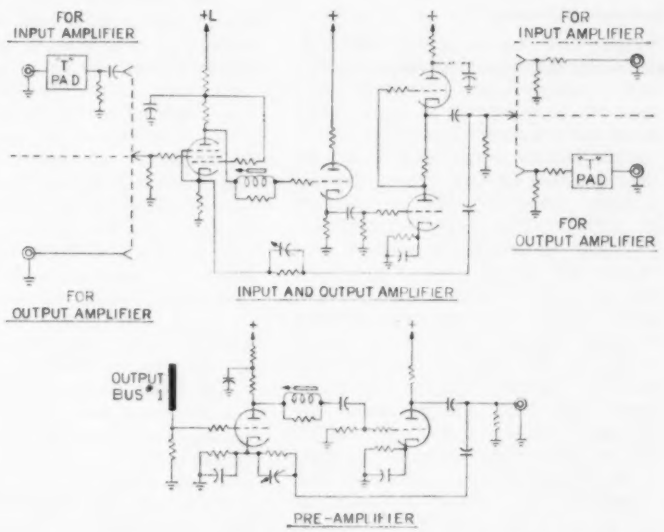

Fig. 2. Detail drawing of the input and output amplifier and the preamplifier.

KA, pushbutton 2 is pushed. Voltage is simultaneously applied to K2 through XL22 and KA through XL23 with KA and then K2 operating. When pushbutton 2 is released, KA releases, thereby energizing the relay hold bus. Since KA releases much faster than K2, the holding contacts through XL21 and the energized relay hold bus keep K2 operating. When pushbutton 1 is pushed, KA and then K1 operate. With KA energized, there is no voltage on the relay hold bus and relay K2 releases. When pushbutton 1 is released, KA releases and energizes the relay hold bus, and through XL11, K1 stays in its "operate" position.

The diodes XL11, XL21, etc., are silicon diodes used to prevent any feedback of hold voltage from one relay to another. The diodes XL12, XL13, XL22, XL23, etc., are used for the same purpose, i.e., to prevent the operation of any relay other than the selected one.

The two form-C contacts were used on each pushbutton for reliability purposes. Should one contact fail to operate the other is still available.

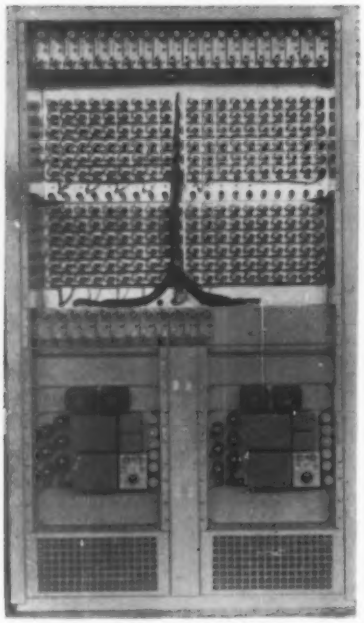

Fig. 3. The complete switcher in its cabinet.

Switcher Mounting

Figure 3 shows the detailed layout of one of the switchers. The output amplifiers are mounted on top and across the switcher rack. Below that is the relay switching system. The input buses are mounted on the front of the chassis and the relays and output buses are on the back. The compensated divider networks are mounted on the input buses with the take-off lead going through the chassis to the relays. This method of construction helps reduce the crosstalk figure by a considerable degree.

The preamplifiers are mounted in approximately the center of the output buses. This helps to reduce the inductive effect of the long output buses. This same technique is used on the input buses where the input coaxial cables from the output of the input amplifiers connects to the input buses.

Below the relays are the input amplifiers. The power supply and power control section with the forced-air cooling system is split into two sections.

Performance of Switcher

The specifications listed near the beginning of this paper were met in performance as follows:

(a) The switching system is capable of accommodating an input of 5 v peak-to-peak and provides an output signal of up to $2\frac{1}{2}$ v peak-to-peak with a negligible amount of distortion on a sine-wave signal.

(b) The bandwidth is flat to within ±1 db to 17 mc.

(c) The gain of the overall system is adjustable from 0.1 to approximately 2.0.

(d) Differential gain at an output level of 1 v is approximately 5%.

(e) Crosstalk between signals is over 40 db down at 17 mc and decreases with frequency at a rate of better than 6 db/-octave. Below 1.0 mc, the crosstalk is better than 60 db down.

All other specifications, such as signal impedance, switching transients (down to a negligible level), switching time, power source, etc., were also met.

Semiconductor Switchers

Other systems of video switching have been evolved since the original relay switcher was designed and developed by Tarc Electronics, which now has a number of 10-mc semiconductor video switchers in the field. Experiments have shown that through the use of a semiconductor as the switching element, a pair of germanium diodes which are biased off or on and thereby letting a video signal go through, an excellent very wide-band switcher may be designed which requires no relays and which gives a decrease in volume amounting to at least 4:1. Bandwidths of 20–25 mc are easily obtainable.

An Automatic Sensitivity Control for Monochrome Film Cameras

By S. L. BENDELL
and K. SADASHIGE

The problem of accommodating unpredictable variations in average density of films and slides used in TV programing has spurred interest in devices for automatic control of signal levels from vidicon camera chains. A practical device provides control over a wide range of densities, with the particular advantage that the method of injecting control avoids introduction of "bounce" into the video signal.

Since vidicon film cameras were first introduced for broadcast use in 1953[1] they have gained wide acceptance in the United States and in many foreign stations. The vidicon characteristics of freedom from variable shading and excellent signal-to-noise ratio have become relatively commonplace and have been mainly responsible for the improved quality of motion pictures reproduced in television systems. The vidicon camera development may also be responsible for the increased emphasis on motion-picture films for television programing during the past five years.

One of the concepts introduced with the vidicon system was that of *constant quality of performance*. For example, by varying the light output from the projector, the same peak-to-peak video signal can be produced by the vidicon camera tube even though the highlight transmission of the film varies over wide limits. Thus the same high signal-to-noise ratio can always be obtained, regardless of film density.

Up to this time the operating parameters of the vidicon have been fixed and the highlight illumination on the vidicon faceplate was kept constant by the use of a tapered neutral density disk between the incandescent light source and the film gate. Thus if film density increased, the neutral density disk was rotated to transmit more light from the source to the film. This was not possible with the old iconoscope cameras since the necessary light reserve did not exist. Another method of obtaining constant quality of performance by entirely electronic means, varying the vidicon operating parameters, will be discussed later.

The concept of constant performance was preceded by a naive period in which we had hopes that film for television would he held to tight tolerances having a highlight density of 0.3 and a lowlight density of 1.8. However, we were rapidly brought by the broadcasters to a realization that film for television often departs from these ideal figures. In fact, a typical sampling indicated that the highlight transmission of film which was expected to perform in broadcast television ranged from 80% transmission to 3% transmission, depending on the type of material used. It was realistic to say that any film which was available anywhere in the stock pile would be run through a television system without regard to its characteristics, and would be called on to produce "acceptable" pictures.

After a series of tests it was found that the most elegant method of light control was that of using a neutral-density filter light-control interposed between the projector lamp and the film gate. Then, it was the duty of the video operator to adjust the amount of light reaching the film so as to maintain *constant* highlight illumination on the face of the vidicon tube and thus obtain the usual 1-volt video signal level under all conditions of film density. The light control range of 100 to 1 actually took care of even the most violent variations in film highlight transmission characteristics.

It is apparent that neutral-density disk control depends entirely on the diligence of the operator whose reaction time and attentiveness determine the quality of the final picture. Perhaps one of the most difficult transitions to handle is that from extremely dense film to a splice of extremely thin film. In this case, the amount of light which goes through thin film is sufficient to overexpose the vidicon to the extent that all information in highlights is completely washed out. Only by dropping the light intensity can the video operator regain control. His reaction time, assuming he is at all alert, is of the order of one or two-tenths of a second. This is small compared to the factors which really limit the system reaction time, the inertia of the disk and the drive motor. These, rather than the human factor, set a minimum limit which may approach a second of time for wide, sudden density variations in the film.

Even in the early stages of development it was known that the effective sensitivity of the vidicon varies directly as a power (more than square) of the target voltage. In fact, the first experimental cameras delivered to the broadcasters used manual target control as a method of providing constant signal output and constant signal-to-noise ratio. Since that time, equipment has come into use which provides automatic target control. The method for carrying this out is quite straightforward. It consists of sampling the peak-to-peak video voltage with conventional detectors, passing the resultant voltage through a d-c amplifier which, in turn, varies the target voltage at the base of the load resistor in such a direction as to maintain constant video output against variations in film density. It is important to point out that only since the development of the RCA 7038 vidicon[2,3] has it been possible to vary the target voltage over wide limits to control the effective sensitivity without introducing "porthole" or landing errors.

One of the difficulties of this scheme is that the target correction voltage can be considered as a low-frequency video signal which is introduced at the base of the load resistor. Thus, any transients associated with target voltage change are fed directly into the feedback loop through the video amplifier, causing this loop to tend to oscillate. This, in turn, shows up as rather severe "bounce" transitions between scenes. The condition can be improved by lowering the loop gain or increasing the time constant of the system. Low loop gain restricts the range of operation and a longer attack time or time constant increases the system reaction time. Experience indicates that such a system can be made to operate satisfactorily if the target control range is limited to a maximum of 10 to 1 in transmission density and if the attack-time is no shorter than two-tenths of a second. Thus, if the film transitions are small and little control is required, the feedback bounce is quite tolerable. For a large sudden transition the lost time may be as much as a second. However, the system is superior to a sleepy operator with normal reaction time. The general arrangements of such a circuit are shown in the block diagram (Fig. 1).

The goal of a practical system is to take care of wide transitions in highlight density which can occur at a very rapid rate, as in switching slides through a still projector. Here, the actual show time of the slide may not exceed a few seconds, and the "lost-time" during the transition presents a very severe

Presented on October 7, 1959, at the Society's Convention in New York by H. N. Kozanowaki who presented the paper for the authors, S. L. Bendell and K. Sadashige, Industrial Electronic Products, Radio Corp. of America, Camden 2, N.J.
(This paper was received on February 24, 1960.)

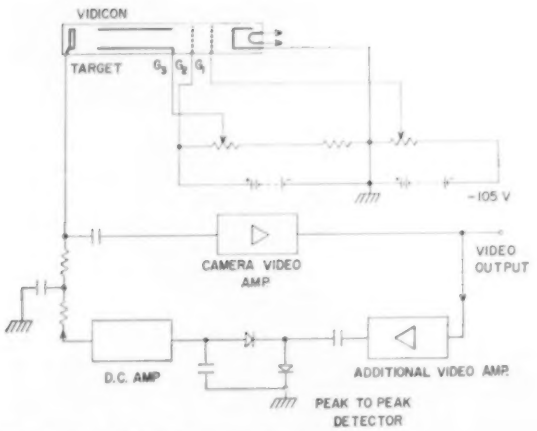

Fig. 1. Conventional automatic target control.

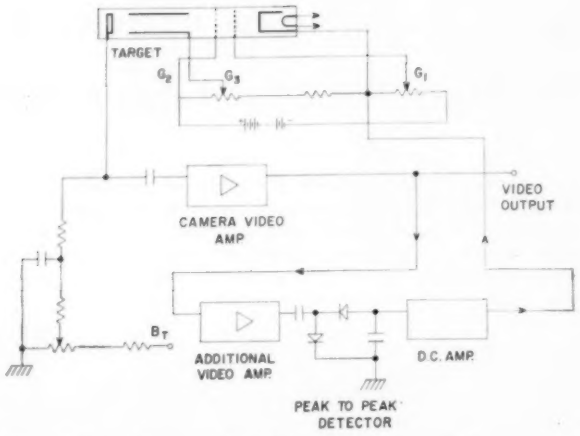

Fig. 2. Improved automatic vidicon sensitivity control.

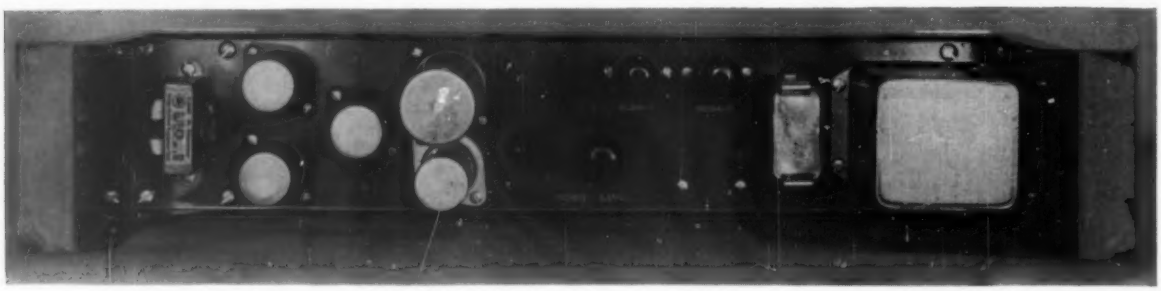

Fig. 3. Vidicon automatic sensitivity control unit.

handicap, particularly in the transition from dense to very thin film material, since the original display of the new material is completely washed out and then recovers intelligibility as the system stabilizes. In order to improve on this, a different approach to the control of dynamic sensitivity of the vidicon was tried. A block diagram of this system is shown in Fig. 2.

In this case, the target voltage is kept at a fixed potential, the video signal output of the tube is measured to find its peak-to-peak value, this direct current is passed through a d-c amplifier and now varies the potential of the *cathode* of the vidicon tube in accordance with the requirements of keeping output signal constant. In this way, there are no surges in the target circuit and the time-constant of the system can be made very short (less than 1/30 of a second) even with loop gains high enough to give 100 to 1 range capability.

In order that the target sensitivity can be controlled by this means (since the vidicon sensitivity is a function of the voltage between target and cathode), all of the other electrodes are fed from a regulated power supply which actually *floats* with respect to ground and is connected to the vidicon cathode.

Even under the worst condition a transition from extremely dense to very light film (100 to 1) can be accommodated in less than a tenth of a second. The stability of the system is good — there is no tendency to bounce or flutter. It is important to emphasize that any automatic device of this nature can never substitute for subjective judgment of an alert operator, especially in "trick" scenes; however, the system has the virtue of always being on hand and regaining control much more rapidly than a casual operator. It should also be pointed out that there is a perceptible shift in transfer characteristic when wide ranges of density are encountered. In general, when the film density variation does not exceed 5 to 1, the amount of gamma shift is not readily perceptible to a trained operator. However, when the range approaches 100 to 1, then the transfer characteristic becomes steeper at higher target voltages. Since the transfer characteristics of abnormally dense film are far from ideal to begin with, this shift of gamma does not appear to be one which should cause great alarm.

An automatic sensitivity control unit designed for use with TK-21 vidicon film chains is shown in Fig. 3. Such units are now available from current production.

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Slow-Motion Recorder for Television Pictures

By H. HIWATASHI, E. MIO and T. KITAGAWA

An arrangement with a standard camera has been devised to televise sporting events having fast action and to broadcast these in slow motion, with very little delay. Successive fields, at 60/sec, are recorded as separate frames on 16mm film which is developed in a rapid processor, then broadcast as standard film. The speed ratio is 2.5 : 1, and the delay 1.5 min. A film storage allows 14 min of showing time (5.6 min original scene time).

In the sports motion picture, the speed of the motion of the photographed body is reduced to about 1/2.5 by increasing the number of frames when the details of a very rapid action are to be shown. If a similar effect is to be obtained in television, it is desirable that the slow-action scene be shown less than one minute after the actual scene has been picked up and televised. The process requires recording the scene on some other medium. The easiest means of attaining this is by film recording. Since this process, which involves recording, developing and reproducing the video signal relayed over the microwave link, can be executed at the broadcasting station, reduction of the time up to the reproduction would be comparatively easy. However, as the number of frames in film recording cannot be chosen as freely as in the case of a motion picture, a 60-frame/sec film is made by picking up every field per frame thereof. When this film is put through the conventional 24-frame/sec reproduction, the speed of the motion can be reduced to 1/2.5, making it possible to show a continuous slow-action film just as in the case of a motion picture (Fig. 1).

The video signals from the cameras in the field (image orthicon) are transmitted to the TV station by microwave link or coaxial cable. The video signals from the camera in the field are then displayed on the cathode-ray tube of the television recorder and the images are photographed on 16mm film. The film is immediately processed by the rapid film processor and then televised by television projector and film pickup camera. The television recorder is operated at a rate of 60 frames/sec and the reproducing projector is operated at a rate of 24 frames/sec.

A contribution by H. Hiwatashi, E. Mio and T. Kitagawa, TV Research Section, Technical Research Laboratory, Japan Broadcasting Corp., NHK, 361 Kinuta-machi, Setagayaku, Tokyo, Japan. (This paper was first submitted on June 6, 1958, and in final form on March 7, 1960).

The Principle of the 60-Frame Recording Camera

As it is not easy, from the engineering standpoint, to pull down the film at a vertical blanking interval, a continuous-motion camera is used here. The film is continuously fed at a constant speed of 60 frames/sec. The arrangement is shown in Fig. 2. On the film aperture the vertical scan velocity is equal (with a normalizing factor equal to magnification) to that on the picture tube screen. On the film surface the scan velocity is equal to the sum of this and the film velocity. This gives the equation

$$v = h + c$$

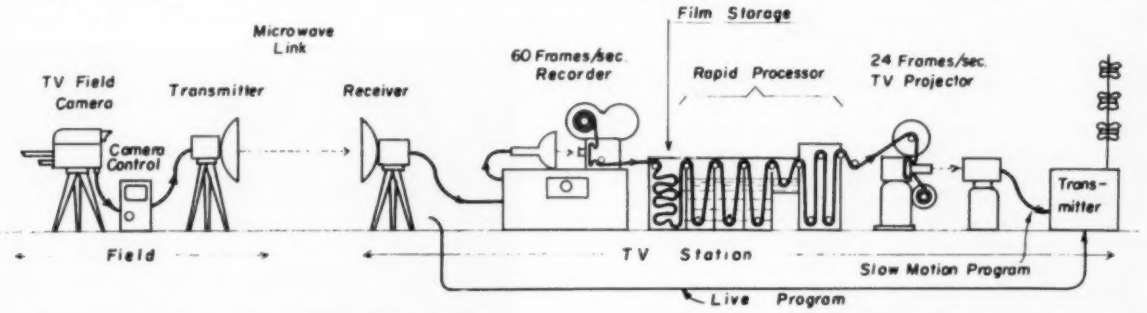


Fig. 1. Slow-motion recording and reproducing system.

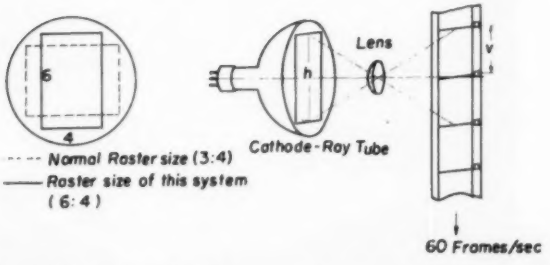


Fig. 2. Optical relation between raster and film image in this system.

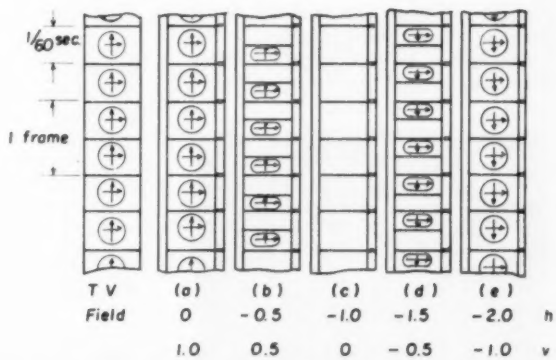


Fig. 3. Relation between images on cathode-ray tube and on film. Film is supplied continuously with the speed of 60 frames/sec. Note: h, vertical height of the image on cathode-ray tube; v, vertical height of the image on film.

Fig. 4. The 60-frames/sec television recorder.

where v = normalized scan velocity on film
h = normalized scan velocity on picture tube screen
c = normalized film velocity

Travel of film during $\frac{1}{60}$ sec equals 1 frame height. In these units $c = 1$ and the other symbols give scanning travels in $\frac{1}{60}$ sec, or picture heights. Possible combinations are listed in Fig. 3.

To make $v = 1$, it would be necessary to make $h = 0$. This means that the vertical scanning will have to be given up, and the phosphor screen would be damaged. Therefore, if h is made to equal -2, then v would equal -1. In other words, if the vertical scanning of the raster is reversed and v is doubled, an inverted picture of correct size can be obtained on the film (Fig. 3). If the vertical deflection of the film camera is reversed at the time of the film reproduction, pictures obtained with this process return to correct position.

Figure 4 shows a continuous-motion camera using a Fujinon F/2, f = 25mm lens and driven with a synchronous motor ($\frac{1}{20}$ hp) with a d-c field excitation. The film with the photographed pictures is directly fed into the rapid processor without winding it up.

Figure 5 is a block diagram of the recording unit. The picture tube is

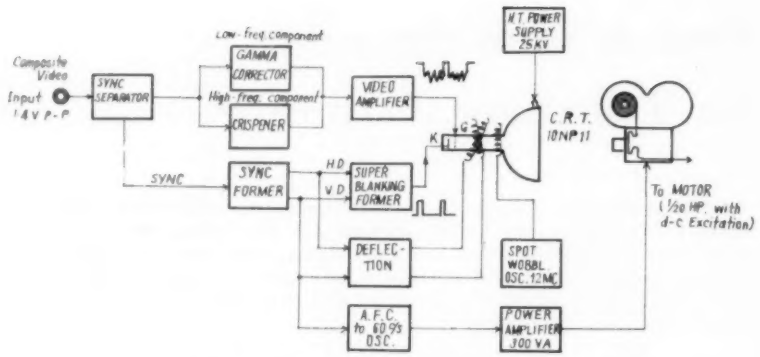


Fig. 5. Block diagram of 60-frames/sec television recorder.

10NP11, with the ultor voltage of 25 kv, and the camera is driven with a 60-cycle power obtained from an electronic power source, locked with the vertically synchronizing pulse by AFC (automatic frequency control). The input video signal is 1.4 v peak-to-peak, and the input that flows into the picture tube after passing through the gamma corrector and the crispener is 30 v peak-to-peak. Its bias voltage is -48 v. The film used is Fuji Film's 16mm, low-contrast positive stock.

Automatic Rapid Processing Equipment

The film is fed into this equipment immediately after photographing. Since there is an accumulation of film due to the difference between the speed of the film at the time of photographing and that of reproduction (0.9 ft/sec), a storage tank is provided at the end of the processor. The processing speed is 24 frames/sec. The storage tank is capable of storing up to 500 ft of film. It is, therefore, possible to cut a 14-min reel of film (Fig. 6).

The film passes through the developing bath, the fixing bath and the washing bath, after which it passes into the drying box. It is then reproduced with a TV projector. Sodium hydroxide is used as accelerator of the developer while ammonium thiosulfate is used in the fixing bath (Table I). Both the developing and fixing operations are conducted at temperatures between 30 and 40 C. For fixing and washing, a jet spray

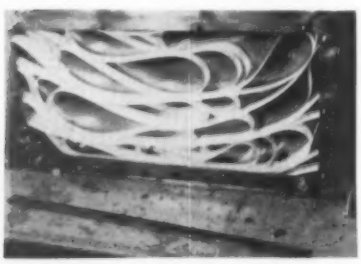


Fig. 6. Film storage box. Capacity is 500 ft, which makes it possible to use a 14-min reel.

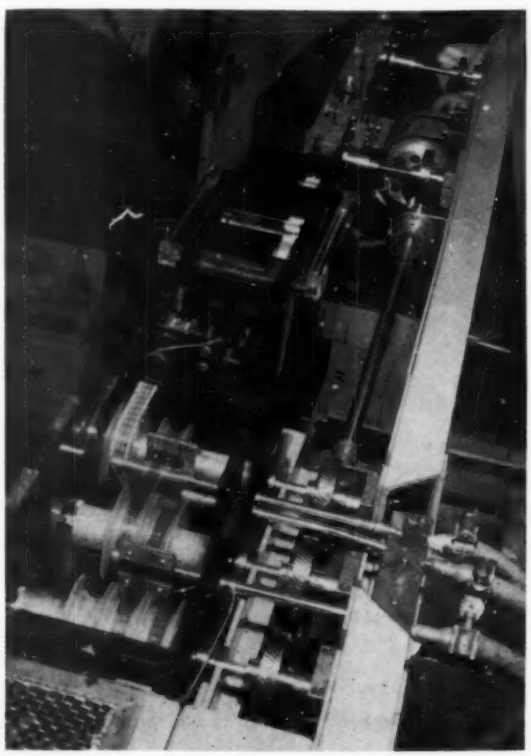


Fig. 7. The rapid processor which has a total processing time of about 60 sec.

Table I. Film Processing Solutions.

Developer		
A Solution		
Metol	5	g
Sodium Sulfite, anhydrous	70	g
Hydroquinone	60	g
Potassium Bromide	20	g
6-Nitrobenzimidazol	0.1	g
Water make to	1,000	ml
B Solution		
Caustic soda	100	g
Water make to	1,000	ml
Add B to A solution before use		
Fixer		
Ammonium Thiosulfate (1:4)	1,000	ml
Sodium Sulfite, anhydrous	7	g
Acetic acid, glacial (28%)	3	ml
Sodium metaborate	7	g
Potassium Alum	7	g

system has been adopted, while drying is done with the application of infrared rays. The time required for processing the entire film is about one minute, with 30 sec more for film passage between camera and reproducer (Fig. 7 and Table II). The sensitometric curves from this processing are shown in Fig. 8.

The reproducer is a 2–3 intermittent TV projector with a vidicon-type camera. The overall horizontal limiting resolution is 500 lines.

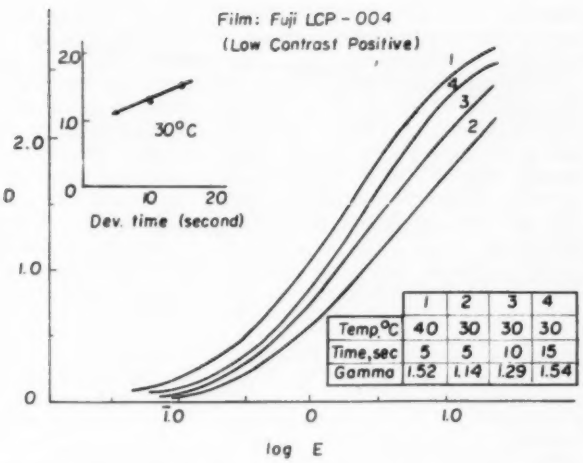


Fig. 8. Sensitometric curves of rapid processor.

Table II. Processing Time, Sec.

Developing	8.0
Fixing	15.0
Washing	8.0
Drying	30.0
Total processing time	61.0
From recording to reproducing	90.0

Acknowledgment

An expression of appreciation is due Hokushin Electric Co., Ltd., which generously consented to design and manufacture the camera and other mechanical parts needed for constructing this equipment. Thanks are also due T. Nomura, Chief of TV Research Section, for his generous advice and guidance.

Letter to the Editor:

Historical Note on Composite Production of Motion Pictures

Referring to the SMPTE *Journal* for December 1959, the article on "Electronic Composites in Modern Television," does not seem to go back far enough to the source of devices designed to combine "rear-view" projected backgrounds and foreground images, with *both* in action.

At the end of the article, under the heading of "Reference," the earliest patent listed is June 16, 1936.

May I call your attention to the fact that all inventions of this nature spring from my original patent applied for on April 3, 1925, which was granted on August 18, 1931. (These were non-electronic, but effective.)

Please find herewith excerpts from this patent, to indicate its general nature. It is necessary to refer to the complete patent to grasp all the possibilities that are covered by it.

To the best of my knowledge, my invention is the very first to be successfully used to combine two distinctly separate images, to appear as a single picture with the combination (background and foreground) in simultaneous action.

I will greatly appreciate your kindness in publishing this information in the *Journal*.

December 21, 1959

MAX FLEISCHER
666 West End Ave.,
New York 25, N. Y.

Editorial Note: No editorial position can of course be taken on patent claims. The paper by Messrs. Kennedy and Gaskins purported to cover only electronic processes for television. Mr. Fleischer's material is, however, of possible historical interest.

Excerpts from U. S. Patent 1,819,883, August 18, 1931, Method and Means for Producing Films, to Max Fleischer:

"This invention relates to a process and apparatus for producing novelties in pictures and has for its object the provision of a process for producing motion pictures on films or other media for

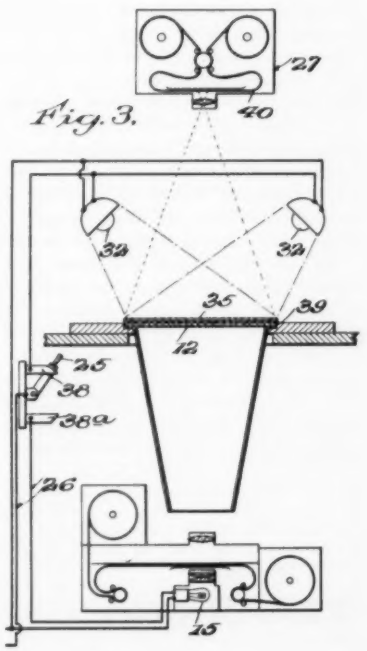


Fig. 3.

projection in which a particular figure may be shown in action or in repose at any point on a background.

"A further object of the invention is the provision of a process for producing moving pictures in which a figure in action is supplied to a definite background which is also in action and so coordinated that the composite pictures will form one continuous medium for projection.

"Other objects include the provision of a device for photographing projected pictures and for photographing other pictures directly on the same film by reflected light, with means for operating the projecting apparatus at will and also for operating a shutter and an instrumentality for taking the photographs, with clutch mechanism controlling the driving of the film to be projected and the negative carried by the camera.

"*Claim 3* — The method of producing negatives for cinematography which comprises forming a projection film containing a plurality of frames and disclosing a series of pictures of a background involving moving elements in different poses, projecting frames of the projection film on a screen, masking the background as projected on the screen except the selected poses of the moving element, photographing selected poses on a sufficient number of raw stock frames of a negative for retaining a selected pose in suspended position, masking the selected poses and photographing other frames in succession disclosing the sequence of the frames of the projection films." [See Fig. 3, reproduced here from the patent.]

Correcting Lenses for Underwater Use

By A. IVANOFF
and PAUL CHERNEY

Submarine photographs, generally taken through a plane window in the wall of the box holding the camera, compare unfavorably with those taken on land, even when wide-angle lenses are used, because of difficulties introduced by the flat window. A submarine lens attachment, consisting of lenses properly chosen and mounted to overcome these problems, is described. The proper powers and diameters of the lenses are discussed, together with corrections for chromatic aberration and astigmatism.

LIGHT WAVES TRAVEL relatively badly in the sea, limiting the possibilities of submarine photography. The selective absorption of sunlight by water necessitates the use of large apertures and, especially for color photography, artificial lighting. Good artificial lighting is difficult to realize, and even the best does not carry very far. The scattering of light is still more troublesome; the photographer finds himself in a luminous mist which diminishes the shadows, cuts down the contrasts and veils the more distant surroundings. It is scarcely possible to diminish the effects of this scattering by the use of colored filters, for the scattering of light by sea water is in general very slightly selective. At present the only way to minimize its effects is to take the photograph or films as near the object as possible, using a camera lens of the shortest possible focal length. This not only gives a reasonable depth of field but requires only relatively feeble artificial lighting. The use of wide-field lenses for submarine photography or cinematography raises, however, a minor problem of optical instrumentation.

Submarine photographs are generally taken through a plane window in the wall of a watertight box holding the camera (Fig. 1). This window acts as a plane surface of separation between the water outside and the air inside the box. Such a surface of separation makes the immerged objects appear nearer and larger in the ratio of the refractive index of water to that of air, i.e., approximately 4:3. The camera lens has therefore to be focused for 3/4 of the actual distance from the object and, what is much more serious, the field and depth of view are cut down. In particular, the camera behaves with respect to the field of view as if it had a lens of 4/3 times its actual focal length. To photograph an object of given dimensions, it is necessary therefore to take the photograph at a distance 4/3 times the distance used with the same camera in air, for example, at 4 instead of 3 m (meters). Even in the very clear waters of the Mediterranean, the radiance of the scattered light between object and camera increases about 40% for an increase in distance from 3 to 4 m. Moreover, the difficulties of artificial lighting increase still more rapidly with increase in distance.

It is possible to overcome in some degree the loss of field of view in submarine photography by using wide-angle lenses; these lenses give, through a plane window, only the field of a normal lens in air. Therefore when this method is used, submarine photography, which demands the largest possible field of view, always compares unfavorably with normal photography on land. The aberrations produced by the flat window reduce, moreover, the quality of the image. The

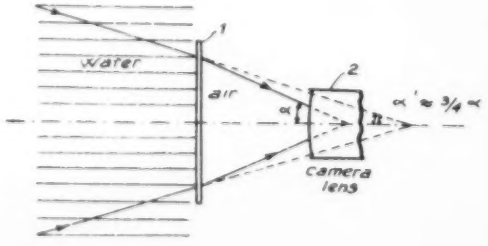


Fig. 1. A window (1) in a watertight box containing a camera lens (2) is placed in contact with the water. This is the system that has been used in the prior art. Such a system comprises a water-to-air plane diopter which diminishes the field, in a ratio equal to the index n of refraction of the water, and introduces besides considerable aberrations at the periphery of the optical field. The field α' of such a device is substantially equal to three-fourths of the field α of the camera lens.

Presented on October 8, 1957, at the Society's Convention in Philadelphia, by A. Ivanoff, Museum of Natural History, Paris, France; and Paul Cherney (who read the paper), Cinefot International Corp., 303 West 42 St., New York 36.
(This paper was first received on October 17, 1957, and in revised form on February 12, 1960.)

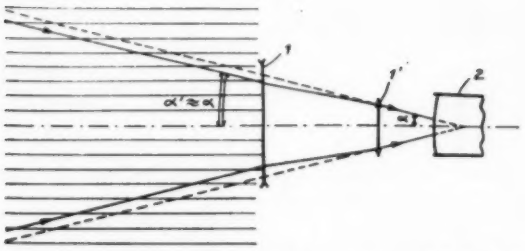


Fig. 2. Correcting optical system to conserve full field of camera lens for submarine photography.

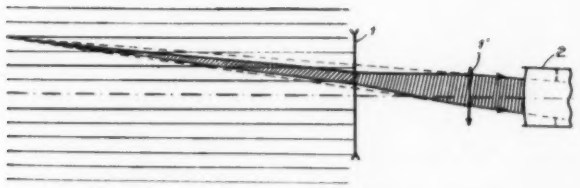


Fig. 3. Same correcting optical system as shown in Fig. 2, comprised of two lenses, (1, 1′), placed in front of the camera lens (2). Such a system provides a virtual image which acts as an object for the camera lens, and this image is superposed upon the immerged object.

chromatic aberration introduced by a flat window is perceptible at distances greater than 5 mm from the center of the film; astigmatism is noticeable for distances less than 2 m using $f/4$, and for distances less than 5 m using $f/2$; and finally, distortion is noticeable when the field of view is greater than 60°. It is therefore desirable to replace the plane window by an optical system that does not introduce aberrations and that permits the taking of submarine photographs with the full field of view of a wide-angle lens.

Advantages of Two-Lens Attachment

These results can be obtained by replacing the plane window in front of the camera lens by a submarine lens attachment such as the Aquar. This attachment, which is mounted in a watertight manner into the wall of the box with its front surface in contact with the water, can be simply formed by two lenses 3 or 4 cm apart and chosen so that:

(1) Immerged objects do not suffer any apparent magnification, and the full angular field of the camera lens can be conserved for submarine photography (Fig. 2).

(2) For submarine photographs at distances between 1.5 and 6 m the camera lens is focused for the real distance of the object, no correction being necessary (Fig. 3).

(3) For a given camera lens with a given aperture, the depth of field obtained is about two times greater than that obtained through a plane window.

(4) The aberrations remain imperceptible for an angular field which can attain 80°, and for an aperture of the order of $f/2$.

Experiment has shown that the centering of the submarine lens attachment need not be perfect, eccentricities of the order of several tenths of a millimeter being permissible. Likewise the distance from the lens attachment to the camera lens can vary by several millimeters without any noticeable deteriorations of the image. These allowances make the use of the submarine lens attachment much easier and permit it to be made an integral part of the watertight box, the camera remaining movable. To mount Aquar correction lenses, the rear surface of its rear element should be as close as possible to the camera lens when the camera lens is set for its shortest range. It is also possible to make the lens attachment part of the camera lens assembly, the whole forming a special camera lens for submarine photography.

In summarizing the features of the Aquar correction lenses (Table I), it may be said that the advantages outlined above can be obtained by means of an optical system comprising only two lenses, the first constituting the porthole or window.

Determination of Powers of Lenses

In order to determine the powers of the two lenses, a basic equation is employed whereby the principal planes of the optical system are both coincident with the object plane. The following result is thus obtained:

$$D_1 \text{ diopters} = \frac{1 - n}{e}$$

and

$$D_2 \text{ diopters} = \frac{-D_1}{n[1 - (e/p)]}$$

where n is the index of refraction of water, e is the distance from the principal image point of the first lens to the principal object point of the second lens, and p is the distance from the principal object point of the first lens to the object plane. The ratio e/p being small, the optical system thus computed for a certain distance p of the object remains quite satisfactory whatever the distance p may be.

Another way for the determination of he powers of the two lenses is to write

Table I. Comparison of Focal Lengths and Angles of View, Uncorrected and Corrected With Aquar-Ivanoff Lens,* Underwater.

Film size, mm	Focal length, mm		Angle of view, degree	
	Uncorrected	Corrected	Uncorrected	Corrected
24 × 36	67	50	36	46.5
24 × 36	47	35	49.5	63.4
24 × 36	37.5	28	60	75.4
24 × 30	53.5	40	39.5	51
24 × 30	40	30	51.3	65
24 × 30	37.5	28	54.0	69
24 × 24	53.5	40	35	46
24 × 24	40	30	46	59
18 × 24	33.5	25	48	62
18 × 24	25	18.5	62	77.5
16	21.4	16	33.5	43.6
(10.4 × 7.5)	20	15	35.5	46
	17.5	13	40	51.5
	15.5	11.5	45	58
	13	9.5	52.5	68

* U.S. Pat. 2730014, 10/1/1956; other patents pending.

that the nodal image point of the first lens is at the principal object point of the second and that the power of this second lens is such that it gives of the intermediate image $A''B''$ a final virtual image $A'B'$ that is superposed on the object AB (see Figure 4). Another feature of the invention thus appears clearly: it is sufficient to modify the power D_2 of the second lens so that the final image $A'B'$ is formed at any desired distance while appearing very substantially under the same angle α' as the object AB. The field of the camera lens will be preserved under these conditions without the virtual image provided by the optical system being superposed to the object.

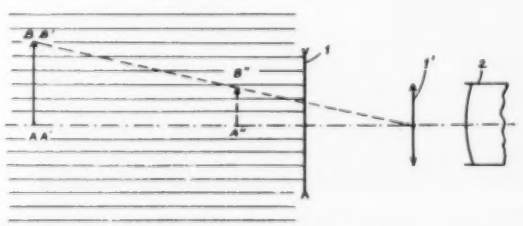
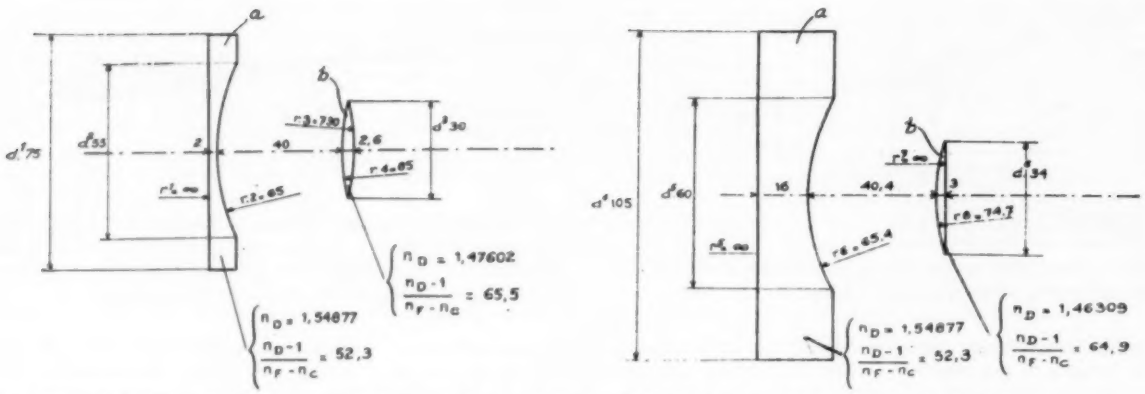


Fig. 4. Nodal image point of first lens (1) in correcting optical system is at the principal object point of second lens (1′).



Figs. 5A and B. Dimensions of two correcting optical systems from which excellent results have been obtained.

Correction of Chromatic Aberration

In order to correct the chromatic aberration of the optical system, it is suggested that an equation be written whereby the powers D_1 and D_2 of the two lenses constituting it are the same for the two rays C and F of the spectrum, for example. Thus one is led to cut out the first lens from a piece of glass material the dispersive power of which is nearly the same as that of the water, and the second from a piece of glass material having a very small dispersive power. It is of course possible, if necessary, to improve the correction of the chromatic aberration thus realized by replacing each one of the two elements of the system, or one of them, by a set of two joined elements having dispersive powers suitably chosen.

Astigmatism Correction

The astigmatism may be corrected either for the light rays not much inclined on the system axis, or for the light rays making a certain angle with the axis — for example, an angle $\alpha/2$ equal to half the field of the camera lens. In the first case, and for a distance π of the second lens to the incoming pupil of the camera lens comprised between 2 and 3 cm, one may choose for the optical system two lenses substantially plane spherical, the two spherical faces set toward each other (Figs. 5A and B). As suggested for the chromatic aberration, it is of course possible to improve the correction of the astigmatism by increasing the number of elements. It is also possible, if necessary, to correct other aberrations in this way.

Diameter of Lenses

Finally, the diameter of the two lenses constituting the optical system is dimensioned so as not to limit the field α of the camera lens. The diameter of the second lens must be greater than $E + 2\pi tg\alpha$ (π being, as above, the distance from the second lens to the incoming pupil of the camera lens, the pupil being of diameter E), whereas the diameter of the first lens must be equal to that of the second, multiplied by the ratio

$$\frac{e + \pi'}{\pi'}$$

where e, as above, is the distance between the two lenses constituting the optical system, and π' is the distance between the second lens and the image of the incoming pupil of the camera lens through this lens. It is fitting, also, to take into account the thicknesses of the lenses (mainly of the first, quite thick at the periphery).

The Aquar lens system will be best understood by referring to Figs. 1–5. Figures 5A and B depict systems which have proven very satisfactory.

Mobility in Underwater Cinematography

By DIMITRI I. REBIKOFF
and PAUL CHERNEY

Use of the conventional submarine in underwater photography is impractical for many reasons, such as monstrous size, poor maneuverability, relative fragility and high cost in money and manpower. The *Pegase* is a miniature submarine designed to overcome these disadvantages. It is easily controlled by one man from within or without and it can move in the water as easily as a fish, or a swimming diver.

THE IMPORTANCE of human presence and operation facilities in underwater cinematography is obvious. Because the human eye is woefully inadequate to record phenomena in water, the motion-picture camera has come to be regarded as a predominant factor in any kind of underwater exploration, and in industrial and military operations.

Cold, exhaustion and the dangerous pressure beyond certain depths are among the factors limiting even the most experienced underwater photographers using only diving equipment. If the photographer works from a conventional submarine or special craft, such as the Piccard Bathyscope, he is again limited by the size of the craft and the lack of maneuverability. Most of these limitations have been overcome in the design of the *Pegase* (Figs. 1, 2, and 3), a miniature submarine that, like a mechanical sea horse, can be easily maneuvered by its rider and at the same time can protect him from the terrors of the deep that beset the lone diver.

Presented on October 8, 1957, at the Society's Convention in Philadelphia by Dimitri I. Rebikoff, Submarine Research Institute, Cannes, France, and Paul Cherney (who read the paper), Cinefot International Corp., 303 W. 42 St., New York 36. An earlier paper by the author, Dimitri I. Rebikoff, was published in *Jour. SMPTE, 68:* 55–60, Aug. 1954, under the title, "Underwater Color Cinematography."
(This paper first received on October 17, 1957, and in revised form on July 23, 1959.)

Experience gained in the development, testing and operation of this torpedo-like submarine, which can be used from the shore, launched from a small boat or from the torpedo tubes of a large submarine, has brought about the concept of various types of miniature submarines which can be efficiently used for many purposes.

Characteristics and Equipment

The standard *Pegase* is constructed of stainless, polished and specially treated duraluminum and it is entirely non-magnetic. Its approximate dimensions are: length, 8 ft; width, 31 in.; hull diameter, 8 in. It weighs about 120 lb in the air and slightly less than 1 oz when submerged in water. The 1.5-hp engine has a speed of $2\frac{1}{2}$ knots, which is the maximum speed which an unprotected cinematographer can attain without losing his equipment. Certain prototypes of considerably higher speeds have been designed, but these units require the enclosure of the diver in the vehicle itself which, of course, requires proportionately greater hull diameter. Full speeds up to 8 knots or more are attainable, with special equipment designed to accommodate the diver at this speed which is well above the human endurance limit. Nose diving as such has no other limits than the safety and endurance of the diver. The equipment itself is tested for approximate depth of 400 ft; its usable depth is 200 ft.

The model *Pegase* discussed here is piloted by means of a gear shift and compensation bar giving complete control of compensated rudders. Through the use of one "joystick," the bow and stern planes are simultaneously controlled to move not in parallel fashion as in the usual submarine but in reverse to each other through a lever or hydraulic equipment. Sideways motion of the joystick turns the left and right bow planes in opposite directions (Fig. 4), making it possible to control a roll even better than in an airplane. Sidewise control of the joystick combined with control of the vertical rudder with foot pedals makes very short turns with very steep banking easy and comfortable.

The engine running time is only slightly curtailed by the use of lights when operating a motion-picture camera (Fig. 5). The normal lights consume 50 amp while the motor consumes 40 amp. An 80-amp set of batteries will give normal working cycles of 2 hr. If the lights run continually without the motor, the running time will be approximately 1 hr 40 min.

If lights and motor are used simultaneously at 90 amp with the batteries running at 80 amp, this will result in approximately 50 min total motor running and lighting time. On the other hand, since the lights are synchronized with the camera, using a 200-ft roll of film will result in a maximum running time of 6 min. The actual impact of the use of lights on the engine running time will be negligible. If desired, two 2000-w searchlights can be installed; they consume 30 min of the running time when the motor is not being used. This

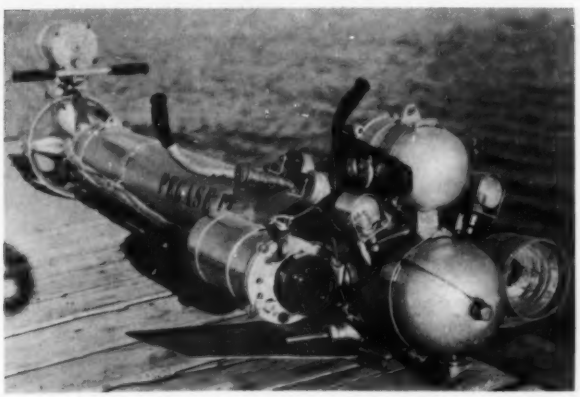


Fig. 1. The miniature submarine is fully equipped for underwater motion-picture photography.

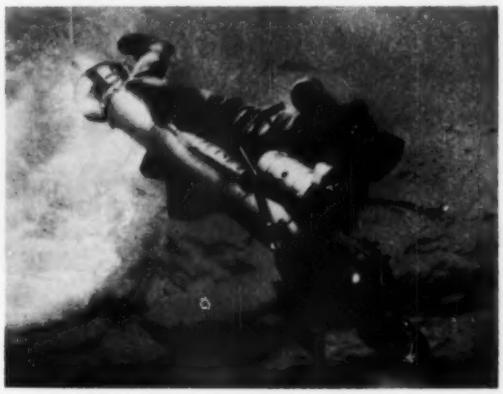


Fig. 2. Thirty fathoms under the seas, the photographer rides *Pegase* at a speed of more than two knots (two nautical miles per hour).

Fig. 3. Inventor Rebikoff demonstrates the maneuverability of the mechanical sea horse.

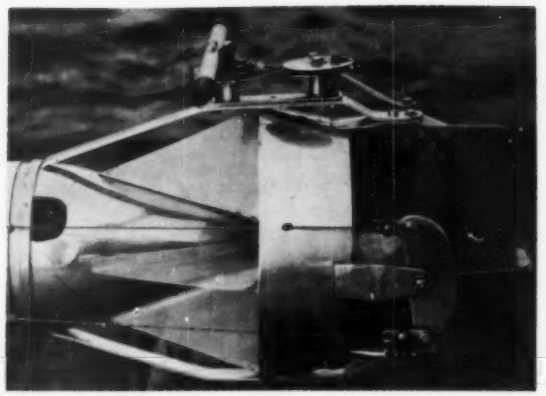


Fig. 4. The *Pegase* steering mechanism reminds observer of old-fashioned "Flexible Flyer" sled. "Joystick" turns left and right bow planes in opposite directions. Short turns and steep banking can be accomplished easily.

is standard equipment for 35mm color motion pictures.

The equipment of the *Pegase II* of the type intended for professional cameramen includes a silver-zinc Yardney storage battery of 100 amp (about 50 discharges), giving a running time of 2 hr 45 min for the engine with no lights on.

The standard instrument panel (Fig. 6) has a compensating magnetic compass, a depth manometer, a chronograph and a warning signal in case of leakage. A more complete instrument panel, which may be made to order, resembles the instrument panel of an airplane. It enables precise navigation in muddy water, at night and in great depths. It includes safety control of gyrocompass, gyroclinometer, transversal and longitudinal static clinometers, compensated magnetic compass, depth manometer, and an instrument to count rotations, in addition to the controls on the standard instrument panel. A powerful light to make night diving possible is controlled from the instrument panel.

Advantages and Applications

The *Pegase* frees the underwater photographer from the limitations of exhaustion, insufficient swimming speed and depth attainment which ordinary diving equipment places upon him.

As compared with the larger types of submarine, the *Pegase* is not only less expensive, but also more flexible and efficient, since it can be used in both shallow and deep water, is maneuverable in small areas and is quieter in operation and less easy to detect. The difference between *Pegase* and a conventional submarine might be compared to the difference between a rigid airship (dirigible) and a helicopter.

Presently there is one basic type in production. This basic type can be variously equipped to suit the particular requirements of the mission.

Units of the *Pegase* type are highly efficient for all purposes — photographic, exploratory, military. Underwater studies in the fields of archaeology, biology, geology, oil deposits and paleontology can be furthered by the use of such units. Such units can also be employed in pearl and sponge diving; industrial and military investigations of modern wrecks; location and neutralization of mines; investigations by Harbor Police of submerged boats, aircraft and automobiles and location of harbor channels.

The first of the specialized units to be based upon the experience gained with the original *Pegase* is the *Jonas*, which is suitable for mine, cable and wreck locations at a shallow depth. This streamlined submarine, with the cameraman enclosed in a canopy, can attain speeds of 15 to 25 knots and can cruise within a radius of 20 to 50 sea miles.

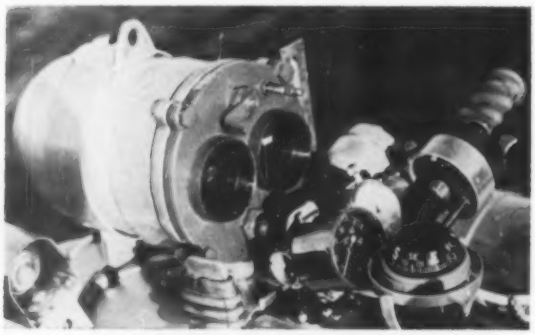


Fig. 5. Stereoscopic motion-picture camera mounted on submarine.

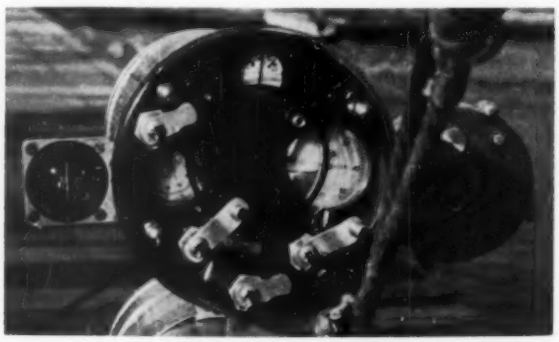


Fig. 6. Instrument panel for a *Pegase* submarine to be used for cinematography.

standards and recommended practices

Proposed American Standards and SMPTE Recommended Practice

Published here for a three-month period of trial and criticism are three proposed American Standards and one proposed SMPTE Recommended Practice. All comments should be addressed to J. Howard Schumacher, *SMPTE Staff Engineer*, prior to July 29, 1960. If no adverse comments are received, the Recommended Practice will be submitted to the Society's Board of Governors for approval; and in the case of the three proposed American Standards they will be submitted to the American Standards Association Committee PH22 for further processing as American Standards.—*J.H.S.*

Proposed American Standard

Speed for 2-In. Video Magnetic Tape

PH22.122

1. Scope

This standard specifies the rate of travel of 2-in. wide video magnetic tape in video-tape recorders.

2. Rate of Tape Travel

The average rate of travel of the tape in a video-tape recorder is 16 (*n*) video tracks per second, where *n* is the vertical synchronizing pulse repetition rate. This is a nominal rate of 960 video tracks per second, for recordings made in accordance with Proposed American Standard Dimensions for Video, Audio and Control Recorder on 2-In. Video Magnetic Tape, PH22.120. This is equivalent to a nominal linear speed of 15 in. per second.

Note: The vertical synchronizing pulse repetition rate, *n*, is nominally 60 pulses per second for monochrome transmissions and 59.94 pulses per second for color transmissions. Departures from these values will result in proportional changes in the rate of tape travel.

NOT APPROVED

Proposed American Standard

Dimensions for 2-In. Video Magnetic Tape

PH22.123

1. Scope

1.1 This standard specifies the dimensions for the width, thickness, and curvature of 2-in. video magnetic tape.

2. Dimensions

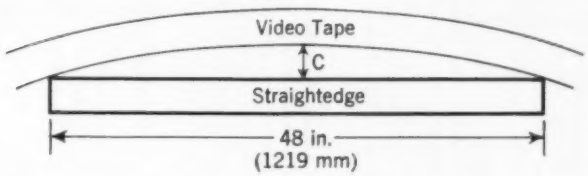
2.1 *Width.* The width of the tape shall be $2.000^{+0.000}_{-0.004}$ in. ($50.80^{+0.00}_{-0.10}$ mm).

2.2 *Thickness.* The overall thickness of the base plus coating shall not exceed 0.0015 in. (0.038 mm).

3. Curvature

3.1 The curvature of the tape shall not exceed 0.0625 in. (1.59 mm) in 48 in. (1219 mm).

3.2 *Measurement.* Curvature shall be measured by constraining the tape to lie in a plane under zero tension and by positioning a 48-in. long (1219 mm) straightedge as shown in the diagram. The maximum deviation, C, of the tape edge from the straightedge shall be taken as the curvature.



NOT APPROVED

Proposed American Standard

Theater Screen Luminance for Indoor Theaters

PH22.124

1. Scope

1.1 This standard specifies the luminance (brightness) of the projection screen for indoor theaters during the projection of 35mm motion-picture film at a rate of 24 frames per second.

1.2 This standard specifies screen luminance levels at which the tone scale, contrast and pictorial quality of the projected image from release prints will be of the quality anticipated during their production, and is intended to provide for such quality throughout the audience area.

1.3 This standard describes criteria for evaluating the suitability of a screen — whether perfectly diffusing or directional — for a particular theater by establishing a luminance level and maximum luminance variations within the audience area.

2. Measurement

2.1 The measurement of screen luminance is made with the projector in complete operation but with no film in the aperture.

2.2 Screen luminance shall be measured with a photometer having the spectral sensitivity of a standard observer as specified by the International Commission on Illumination in 1931. The acceptance angle of the photometer shall be as small as is practical, and shall be so used that it accepts light from a screen area no larger than a circle whose diameter is 10 percent of the screen width.

3. Luminance Level

3.1 The luminance at the center of the screen shall be 16^{+4}_{-6} ft-L (55^{+14}_{-21} nits) as measured from a position on the longitudinal centerline of the auditorium and two thirds distance from the screen to the rearmost row of seats.

3.2 The luminance at a distance 5 percent of the screen width from the side edges of the screen, and on its horizontal axis, shall be between 65 and 85 percent of the center luminance as prescribed and measured in 3.1 above.

3.3 The luminance at any point on the horizontal axis of the screen, between points located at a distance 5 percent of the screen width from the sides of the screen, shall be between 5.5 and 20.0 ft-L (19 and 69 nits) as measured from any seat in the auditorium.

APPENDIX

(This Appendix is not a part of Proposed American Standard Theater Screen Luminance for Indoor Theaters, but is included to facilitate its use.)

A1. *Standard Luminance.* Possible luminance levels are limited by a minimum value below which the visual process becomes less efficient, and by a maximum value above which flicker becomes objectionable. Permissible luminance range is limited by the criterion that a good release print must provide acceptable quality when projected at any luminance within the range.

A2. *Other Variables.* In addition to the luminance distribution, the pictorial quality of projected pictures is influenced by the color of the projection light, the color and characteristics of the screen surface, the presence of stray light, the nature of the surround, and other factors not presently described by standards.

A3. *Preferred Screen Luminance.* This is considered to be that condition wherein (1) the luminance of the center of the screen is constant from every usable seat in the theater and is within the limits of 14–16 ft-L; (2) the luminance of the sides of the screen is approximately 85 percent of the luminance of the center; and (3) the luminance variation has axial symmetry around the center of the screen. The nominal value in 3.1 has been chosen to represent such preferred luminance. The tolerances have been selected to include viewing conditions which experience has shown to be acceptable and to exclude those known to be undesirable. As screen design permits more optimum control of luminance gain, it is expected that tolerances will be reduced and will become more symmetrical.

A4. *Indoor Theaters.* This standard is limited in scope to indoor theaters because it has been observed that optimum screen luminance for projected pictures depends upon the conditions of viewing. Under the conditions of the indoor theater with the screen subtending a large angle at the observer's position, with low stray-light levels, etc., these conditions have been found by experiment and experience to represent the best compromise among the many factors involved, but not necessarily the best situation for drive-in theaters and for auditoriums with high ambient light.

A5. *Directional Screens.* Matte white screens will show substantially constant luminance at any one specific area on the screen for measurements from any location within the theater. Directional screens in current use have been designed to produce specific reflection patterns which on goniometric measurements of luminance from various viewing angles show wide departures from the properties of a perfectly diffusing surface. By suitable choice of such patterns the attainable luminance may be increased considerably above that possible with a perfectly diffusing screen of the same size when measured near the axis of projection, although there may be a significant variation in luminance with viewing position in the theater.

3.3 sets a maximum permissible variation; in a particular theater this condition can be met by several procedures including one or more of the following: choice of a screen with a suitable reflection pattern; limitation of the seating area so that no patron views the picture from an angle at which the luminance is outside the tolerance of the standard; and curvature of the screen. (In practice the curvature of screens whose surface is continuous is limited to a radius equal to or somewhat greater than the projection throw to avoid excessive re-reflection and contrast loss.)

A6. *"Luminance gain"* is defined as the ratio of the luminance of a specified area of the screen to the luminance of a perfectly diffusing and perfectly reflecting surface, both measured under the same conditions of illumination and observation. For directional screens, luminance gain is a function both of the direction of illumination and of the direction of observation. With any given screen these two vectors may be chosen so that the luminance level obtainable is made a maximum, and this condition defines the "maximum luminance gain."

A7. *Limitation on Luminance Range.* Present directi ' screens show a large variation in gain , hanges in the projection and viewing angles, necessitating the 3:1 luminance ranges prescribed in 3.3 when the more desirable screens are fitted into existing theaters. Even this range effectively limits the maximum luminance gain of the screen, and the wider the theater becomes, the lower the maximum luminance gain must be to meet luminance specifications with most existing directional screens. When screen design permits a smaller luminance range, it is intended that this standard be revised accordingly.

A8. *Maximum Screen Size.* Projection light output and screen luminance gain together determine the maximum screen size that can be illuminated to produce standard luminance.

A9. *Meter Acceptance Angle.* The maximum permissible acceptance angle of the luminance photometer will depend upon the instrument design and method of use, the size of the screen and other factors. The acceptance angle of a suitable instrument must be such that a reduction in this angle (followed by necessary recalibration) does not change the magnitude of any reading specified in 2 by more than ±5 percent. The limiting conditions for the reliable use of such meters should be included in the manufacturer's specifications.

A10. *Conversion of Units.* Screen luminance in the U.S. is customarily measured in foot-Lamberts, although in international usage the nit is the preferred unit. 1 nit = 0.2919 ft-L; 1 ft-L = 3.426 nits.

A11. *Image Luminance.* Note that this standard specifies screen luminance with no film in the projector aperture. When films are projected, the average image luminance will be considerably below this level.

PH22.124—NOT APPROVED

Proposed SMPTE Recommended Practice RP 7

Modulation Levels for Monochrome 2-Inch Video Magnetic-Tape Recording

Introduction. In current video-tape recording systems the playback video signal level is dependent upon two independent factors, viz., (a) adjustment of the playback video amplifier gain setting and (b) deviation of the recorded, frequency-modulated, radiofrequency carrier signal. In order to achieve uniformity of playback video signal levels without the accompanying need for readjustment of the playback video amplifier gain, it is essential that all video-tape recordings be made in accordance with the same recommended practice for carrier deviation. This is of particular importance for playback on equipment other than that used for recording, or when the playback tape consists of two or more recordings spliced together.

Recommendations

1. *Scope*

1.1 This recommended practice specifies the recorded modulation levels for monochrome television signals.

2. *Recorded Carrier Frequencies*

2.1 The recorded carrier frequencies corresponding to reference video signal levels shall be as follows:

(a) Reference White Level: 6.8 ± 0.05 mc.
(b) Blanking Level: 5.0 ± 0.05 mc.
(c) Sync Tip Level: 4.28 ± 0.05 mc.

news and reports

Space, Motion Pictures and Television — Embraced

TIROS I, a drum-shaped object 42 in. in diameter and 19 in. in depth, went into orbit April 1 and is now hurtling around the Earth, 400 miles "up there." A radio announcement that the weather-observing satellite had been launched from Cape Canaveral and had gone into orbit came about 6:30 A.M. (EST); about six hours later a 14-min sound film showing the orbiting satellite gave the American public an awe-inspiring view of its launching and a clear view of cloud formations as seen by Tiros's "eye." (The project was named Television Infrared Operation Satellite — hence, Tiros.) The remarkable delivery schedule of this film, a production of Reid H. Ray Film Industries, Inc., was the result of exacting preparation and precise timing.

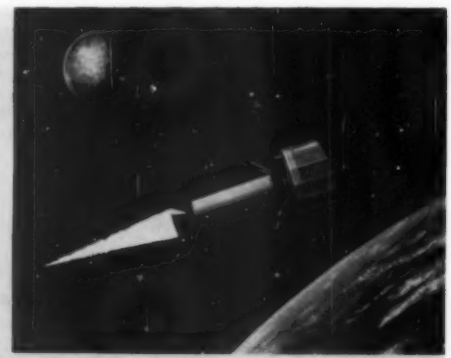
Putting the film before the satellite better tells the story at this stage: Last November script writer Robert Bruce of the Reid Ray Organization was indoctrinated in the classified project TIROS at the Princeton, N.J., laboratories of the Asto-Electronics Products Division of Radio Corporation of America, the sponsor of the film. At the same time, Gordon Ray, Animation Director, began planning the animated sequences.

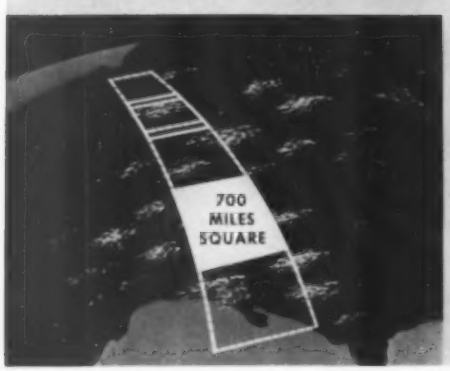
By December it was decided to produce the film in 35mm Eastman color, and a very careful production schedule was established because of the importance of releasing the picture simultaneously with the launch date. Reid Ray, Director of the picture, and his camera and electrical crews spent eight days on location early in December at Princeton. They photographed the various components of Tiros and several assembly stages under actual test conditions. Sounds of the weather satellite in orbit were simulated by the RCA ground station and recorded. Each day's exposed film was rushed to Movielab in New York which developed the color negative and rushed prints back for projection the next day in a theater in Hightstown, N.J. Careful screening of the rushes was necessary: the film was to be released for 35mm wide-screen theater exhibition, TV broadcast and 16mm. The composition of each scene had to be compatible to all three screen ratios.

The film, itself, and the story of its production reflect in a way the concentration of the many kinds of talent, training, skill, immense resources and exacting labors brought together for one purpose — man's tossing into space a strange and special speck for the purpose of adding to the sum total of human knowledge.

The satellite, strictly speaking, is only one component — the information-gathering element — in a complex satellite and ground system developed by the Radio Corp. of America. It was directed into orbit by the Bell Telephone Laboratories Command Guidance System.

Miniature television cameras, video-tape recorders and transmitters within the satellite maintain constant contact with a ground network of tracking and receiving stations, data processing systems and programing and control centers. Tiros encloses two complete television systems capable of taking a series of still pictures of cloud formations during each orbit. Each employs a specially developed RCA $\frac{1}{2}$-in. vidicon camera (small enough to hold in the palm of a hand). One of





Upper left: Animation for Tiros film was completed months before launching.

Upper right: Tiros—propelled into space by third stage of Thor-Able rocket.

Lower left: Tiros TV cameras record cloud formations blanketing the Earth.

Lower right: Artist's conception of the 42-in. Tiros making its 90-min. trip around the Earth at a 400-mi. altitude.

Kodak

He knows everything about photography except how to make film.

He makes the world's best high-speed color film emulsions but tries to photograph pretty scenery through a dirty windshield.

At one of the 170 high-speed camera stations which instrument the 20,000-foot supersonic sled track at Edwards Air Force Base, Lt. Col. Earl R. Strandberg makes the acquaintance of Kodak's Walter A. Fallon. Colonel Strandberg, as chief of the Photographic Branch, has responsibility for quantitatively documenting all phenomena encountered in impact tests, static firing of rocket engines, and other activities of the Air Force Flight Test Center. Mr. Fallon, who is in charge of Kodak's color film emulsions, is visiting to observe the demands to be met by his latest products, a reversal film and its companion duplicating film. They strongly enhance information capacity through fine color distinction, sharpness, and extreme speed.

The names of the new products are **Ektachrome ER Film** and **Ektachrome Reversal Print Film.** They have a realistic quality that stimulates observers to perceive facts in super-slow-motion movies that would be lost without color.

To Walt Fallon the scenic drive through the mountains to check them out with the Colonel brought him near culmination of a hard campaign. To the Colonel, however, they represent only another step in a long history of increasing the usefulness of photography. In 1927 he talked a high school coach into letting him be the first man—more accurately, the first boy—ever to film an entire football game for purposes of analysis and self-improvement.

For information about color photographic materials for recording work, write

Photorecording Methods Division

EASTMAN KODAK COMPANY, Rochester 4, N.Y.

the cameras is equipped with a wide-angle lens for viewing clouds in an area about 800 miles on each side; the other employs a narrow-angle lens to scan cloud details in a smaller area. A miniature television magnetic tape recorder, designed for satellite use, is linked to each camera.

At the start of each orbit, the cameras can be electronically instructed to photograph a specified area — such as a typhoon center over the Pacific, or a hurricane in mid-Atlantic. The instructions, prepared at the NASA Computing Center in Washington in cooperation with the Weather Bureau, are sent to the ground stations. At the appropriate station, the program is sent in the form of radio signals to an "electronic clock" inside Tiros. The clock stores the instructions somewhat in the fashion of a remotely operated alarm clock, causing the cameras to start a sequence of operations at the specified time during the succeeding orbit as the satellite passes over the region of particular interest. As the satellite swings around the Earth and comes again within range of a ground station, a command signal is sent from the ground for transmission of the cloud pictures stored on the tape. At the ground station, the information is displayed on a television picture tube and recorded on another magnetic-tape system. The image on the picture tube also is photographed and stored for future reference by meteorologists.

The purpose of the Tiros system has been defined by Barton Kreuzer, Manager of Marketing for RCA Astro-Electronics Products Division, as "visual observation of cloud formations over large parts of the Earth to produce new information about such weather phenomena as hurricanes, typhoons, and the movement of weather fronts." And Sidney Sternberg, the Division's Chief Engineer, described the satellite as "a major space system complex incorporating advanced concepts in space communications and the remote control of satellite functions."

The radio-inertial command guidance for Tiros is the same system as that developed by Bell Telephone Laboratories and Western Electric Co. for the Air Force Ballistic Missile Division for use in the first squadrons of the Titan intercontinental ballistic missile.

It is interesting to note that only a week before Tiros was launched, a paper presented at the International Convention of the IRE in New York called attention to the "billions lost each year in storm damage" in the United States, and warned of grave consequences if weather research were neglected.

Admiral Luis de Florez, consulting engineer and former Assistant Chief of Naval Research, in addressing a Symposium on "Electronics — Out of the World," called for more manpower and more funds to be devoted to vital research in weather forecasting and control. "Actually, it would be of greater immediate importance to this country to be the first to find the answer to the feasibility and practicability of weather control than to land a man on the Moon," he said.

INTERNATIONAL CONGRESS 1960 5TH SMPTE ON HIGH-SPEED PHOTOGRAPHY

Warren Magnuson, Chairman of the Senate Committee on Interstate and Foreign Commerce, author of S. Con. Res. 75 (*Journal*, Sept. 1959, p. 638; and Oct. 1959, p. 706) has been a strong defender of research and scientific endeavor during his active political career extending over almost three decades. He was elected to the Washington State House of Representatives in 1932; in 1937 he became a member of the U.S. House of Representatives and in 1944 he was elected to the Senate.

Among the many evidences of his interest in science is his sponsorship of legislation to create the National Science Foundation, and he is presently directing efforts toward broadening the scope of its research program. He is sponsor of legislation to get the Navy's Tenoc program in Oceanographic Research funded and underway. The Senate Resolution, referred to above, expresses Senator Magnuson's sincere interest in scientific advancement in general and recognition of the importance of the 5th High-Speed Congress in particular. The Resolution calls for active participation by Federal agencies and was passed unanimously by the Senate.

Education, Industry News

Rapid processing of film is the subject of a symposium of the Society of Photographic Scientists and Engineers will be held in Washington, D.C., October 14–15. It is planned in conjunction with the Fifth International Congress on High-Speed Photography, October 16-22. SPSE Papers Chairman is Fordyce M. Brown, c/o Photomechanisms, Inc., 6 West 18 St., Huntington Station, N. Y. The emphasis will be on compact, simplified photoprocessing equipment with short process time. Primary interest will be in the special techniques associated with development and design, specialized photographic chemistry, and specific uses in science, industry and the military. Depending on time available, reports on design and construction of larger processing machines and on advances in processing methods and control systems may also be scheduled. An introductory paper, "The Revolution in Photographic Processing," will be presented by George Eaton, SPSE President. A technical exhibit of equipment related to reports presented at the Symposium is being arranged.

The Society of Photographic Scientists and Engineers will hold its 1960 National Conference May 9–13, at the Miramar Hotel, Santa Monica, Calif. More than 60 technical papers are scheduled, among them reports on space photography and related instrumentation. A session on photographic engineering will include papers on a new technique for high-speed photography of cyclic events, use of magnesium-filled lamps in high-speed photography, and details of photographic support of research on jet engines. Photographic sessions on processing and apparatus will

At last...
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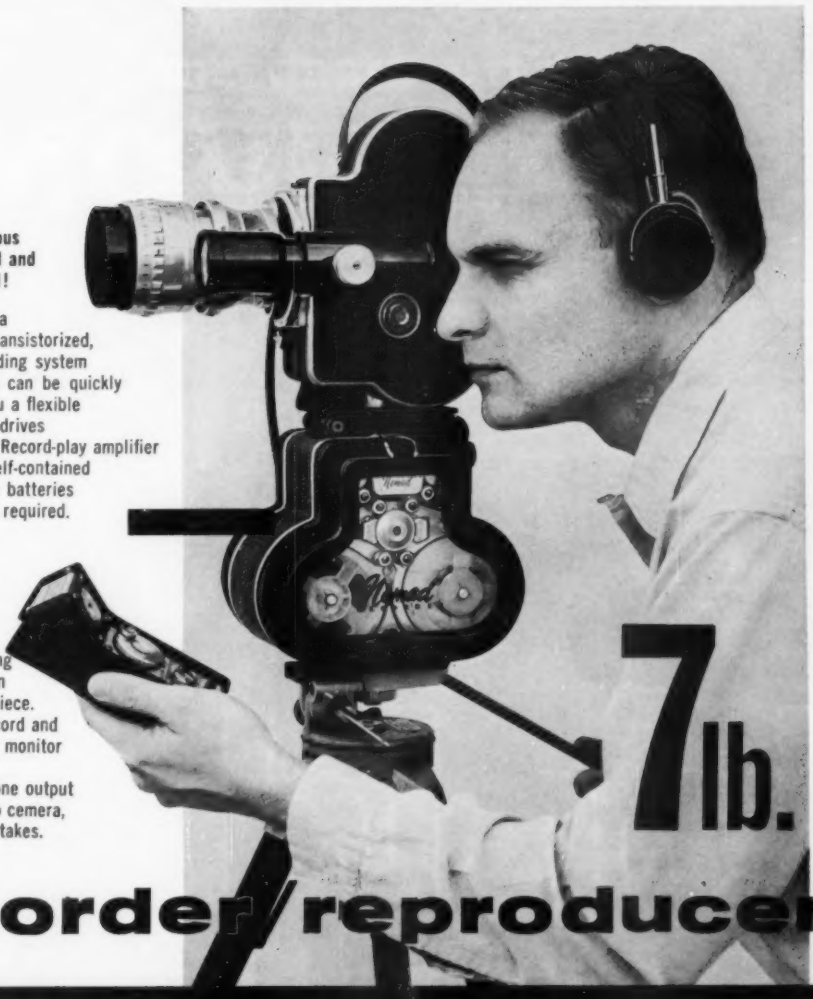
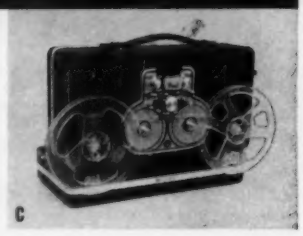
This precision instrument is a completely self-contained, transistorized, portable and versatile recording system to which any 16mm camera can be quickly mounted and interlocked thru a flexible cable. Camera spring motor drives recorder in absolute "sync". Record-play amplifier is fully transistorized with self-contained cadmium-nickel rechargeable batteries ... no other power source is required.

Remote hand mixer permits control of recording levels by thumb movement ... giving operator a "feel" for position while concentrating on eye-piece. Mixer contains VU meter, record and playback controls, film-direct monitor switch, battery test switch, microphone input and earphone output jack. Mixer may be clipped to camera, tripod, belt or pocket during takes.



7 lb. recorder/reproducer

The amazing Nomad makes any movie camera a sound camera, any projector a sound projector in professional "lip-sync"



C

A. Nomad film is split 16mm. Channel #1 on the twin-track record head is used for lip-sync and narrative recording on location. Later, complimentary music from phonograph or tape recorder is "dubbed" on channel #2. Simultaneous playback thru the full width play head mixes music and voice, producing theatre-quality sound.
B. For lengthy sequences, a regular camera D.C. motor can be attached to the Nomad, driving both recorder and camera thru the flexible cable. There is a 180 rpm output in the Nomad camera interlock and a 1440 rpm output for projector interlock. Playback can be double-system, or a 1:1 interlocked transfer from recorder to a striped release print can be made with a magnetic sound projector.
C. Basic film capacity is 100 ft.; the use of simple adapters can increase capacity to 400 ft. or 1200 ft. Entire Nomad system fits compactly into small carrying case.

Editing is easy with an inexpensive synchronizer and a sound reader. Since each roll of Nomad film is exactly the same length as the picture film, points of reference for editing are easily provided.

price $585

Basic Nomad system consists of recorder-reproducer, remote hand mixer and camera mount. Other accessories are available.

dealer inquiries invited

Write, wire or phone

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cover a simplified approach to automatic dodging control, fast processing by means of a chemical-saturated paper, the EN-37 printer for use with gun cameras, and varied scientific uses of commercial monobaths. Other major conference categories include optics and image structure, motion pictures, and color materials. A technical exhibit will be held in conjunction with the Conference.

The SPSE will extend membership registration privileges to all SMPTE members.

Plans for a Hollywood motion-picture and television museum have been discussed, off and on, for a number of years, with hearty approval for the idea expressed by all concerned, but the progress of the dream toward reality has been hampered by many obstacles. A step was taken in 1953 when the Motion Picture Relief Fund, under the leadership of the late Jean Hersholt, attempted to raise $1 million for the purchase of the Paramount Sunset Studio to be used as a museum. This attempt failed; but six years later, in June 1959, the appointment of a Commission, empowered to formulate and put in effect plans for the museum, by the Los Angeles Board of Supervisors seemed virtually to assure the eventual construction of the long-dreamed-of museum. Civic recognition of this project seems to be in accord with a growing awareness of the historic significance of the early days of motion pictures and television and the need for preserving records of the past. An informal report from a Hollywood member of the SMPTE Historical and Museum Committee, Syd Cassyd, recounts progress on two such projects: On Establishment of Two Archives in the Los Angeles Area.

Two important steps in collecting and archiving materials and equipment of motion pictures and television were made this past year in the Los Angeles area. The first was the establishment of a Commission on Motion Pictures and Television Museum by the Board of Supervisors of Los Angeles. Appointment of many prominent persons in the industry focused attention on this problem. Sol Lesser was appointed Head of the Commission. A site has been chosen and plans for the construction of a suitable building have been formulated. The site is close to the Hollywood Bowl which is next to the Los Angeles Freeway system which means that the proposed museum will be easily accessible to everyone in Los Angeles and surrounding areas.

The second development in the field of collection and preservation of historic records was the appointment by the Chancellor of the University of California, Los Angeles, of an Honorary Curator of a proposed Television Archives. The appointment was made in accordance with a suggestion made by the Head of the University's Television Library Committee. It is hoped that this appointment will have the effect of speeding up the difficult job of collecting materials and programs which are slowly disappearing, particularly those of the years preceding 1946 and the 1946–1949 era. This project has been underway since 1956 when the Chancellor, in cooperation with the Academy of Television Arts and Sciences, appointed a committee to study all aspects of the project. Problems of space, and clearances for guilds, unions and finances have been the main roadblocks to collection. The networks and local stations are cooperating and it is hoped to report progress soon.

A one-week seminar in Electronic Flash and High-Speed Photography will be held at the Massachusetts Institute of Technology August 15–19. The meetings will center at the Stroboscopic Light Laboratory where the theory and application of various methods will be studied. Mornings during the program will be devoted to theory and demonstrations; laboratory practice sessions will be held

Test Film Resales

It has come to the attention of the Society that a quantity of several types of SMPTE Test Films which were produced some years ago, are now being offered for resale. Due to the fact that the physical characteristics and the useful life of film may be affected by the conditions and length of storage, the Society can make no representation as to the conformance of such films with established Society standards.

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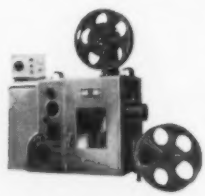

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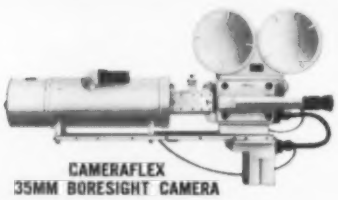

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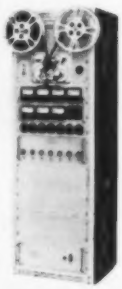

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during the afternoons. Subjects to be covered include pulsed stroboscopic lighting, optical high-speed cameras, Kerr cells, Faraday shutters, and image converters. Specialists in high-speed photography have been invited to lecture on their particular subjects. The seminar will include laboratory demonstrations of many types of equipment related to high-speed photography. The program will be under the direction of Prof. Harold E. Edgerton of the Department of Electrical Engineering, M.I.T. Tuition is $175. Academic credit is not offered.

A trend away from the "learning more and more about less" type of specialization and toward the "Renaissance man" type of diversified learning was hinted at by Hans H. Zinsser, M.D., Chairman of the Medical Electronics Session at the International Convention of the Institute of Radio Engineers held in New York, in March. In discussing medical engineering foreseen as a new profession, Dr. Zinsser spoke of "a new breed competent to talk in both fields, not only through acquisition of a vocabulary, but trained in ways of thought that summarize much more than medicine, or engineering, or basic biology comprises at the present time. It is by the development of such multiple-faceted minds that we can most readily progress to the full realization of the potentialities before us."

Dr. Zinsser outlined a suggested curriculum leading to a degree in medical or bio-medical engineering.

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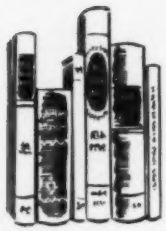

books reviewed

Principles of Optics

By Max Born and Emil Wolf. Published (1959) by Pergamon Press Inc., 122 East 55 St., New York 22. v-xxvi + 803 pp. including illus., charts, graphs, etc. 6¼ by 9¼-in. Price $17.50.

It is interesting to note that much of the brilliant work done in optics in the second half of the nineteenth century is still perfectly valid and in continuing use. But the broadening scene of physics has elucidated many points that remained mysterious at the close of that period. The optical accomplishments of the twentieth century are constantly revising the point of view in this field.

The present book is a re-working of an earlier *Optik* by the senior author, Max Born. There have been many changes, and the volume is practically a new work. In several respects it is more, perhaps, to be compared with the famous *Lehrbuch der Optik* of Paul Drude. This came out at about the turn of the century (in English translation only by 1922). The comparison consequently reflects a half-century of development in optics.

The broad objectives of the *Lehrbuch* and the present work are really much alike — to present a systematic and unified theory of the major optical phenomena.

The subject matter of the two books is surprisingly similar. Simply, it covers the production of images by lenses and mirrors, interference and diffraction phenomena, the many phenomena of polarized light and its transmission through crystals, and the optics of conducting media such as metals. Some of this is treated by the use of geometrical optics, but most of it needs the more fundamental wave theory.

The first difference that one notes is in the order of presentation. Drude started with the straight geometrical optics. When he introduced waves, he managed as long as possible with an equivocal mechanistic medium. Electromagnetic waves appeared only very far along in the book.

Born and Wolf start right out in the very first chapter with Maxwell's equations. It is only after a hundred pages that they show how the equations lead to the rectilinear light rays of geometrical optics, and they then proceed to go into image formation.

The authors gather together all the material dealing with partially coherent light into a single chapter. Drude treated bits of this here and there as he dealt with Young's fringes, breadth of spectral lines,

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and other subjects. The modern information theory approach unifies and clarifies this field considerably.

One notices a difference in the general plan of attack on explanations and derivations. Where the older book was heuristic and tentative, Born and Wolf are sophisticatedly analytic, as befits the accumulation of knowledge which has occurred in the interim. One must admit that the reader can pay a certain price for sophistication, in that comprehension does not always come so easily.

In dealing with the design of imaging systems, a major element is the theory of aberrations. If one is to evaluate the preference of one design over another it is necessary to have such a quantitative criterion of performance as indicated by the aberration. The fundamentals of geometrical aberrations run back as far as Seidel in the 1850's, and of wave or diffraction aberrations to Lord Rayleigh around 1880. Born and Wolf present the material in two chapters, in a particularly comprehensive discussion. Its modernity is indicated by the references, running to 1957.

A number of chapters in the book have been written by other than the titular authors. Among these is a detailed discussion by Professor A. B. Bhatia on the diffraction of light by ultrasonic waves. Similarly a chapter on rigorous diffraction theory (as distinguished from the earlier use of Huyghens' principle) and a mathematical appendix were contributed by Dr. P. C. Clemmow. Other material was prepared by Drs. Wayman, Wilcock, Stokes, and Professors Taylor and Gabor.

There are some very detailed appendices to cover certain mathematical tools used in the text, such as the calculus of variations (adapted from Hilbert's 1903 Goettingen lectures), the Dirac delta function, the circle polynomials of Zernike, etc.

The book is fairly strictly limited to the theoretical reader. There is a chapter on image-forming instruments, but this material is fairly sketchy and illustrative, and not really meant to guide the practical individual.

The book will presumably become a standard reference work in the field of theoretical optics. It is suitable as a text for advanced students.—*Pierre Mertz*, 66 Leamington St., Lido, Long Beach, N.Y.

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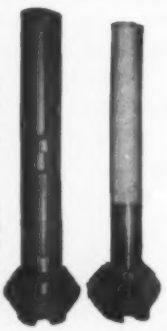

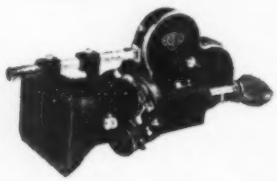

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Professional Association in the Mass Media:

Handbook of Press, Film, Radio, Television Organizations

Published (1959) by the United Nations Educational, Scientific and Cultural Organization, Place de Fontenoy, Paris 7, France (U.S. Agent: UNESCO Publications Center, 801 Third Ave., New York 22). 206 pp. 8 by 10½-in. Price $5.00.

This useful and informative handbook lists alphabetically, country by country throughout the world, organizations for the press, film, radio and television. Each organization is listed with its address, scope and purpose, membership, qualifications for membership, publications, history, and names of officers. Part I of the handbook lists international organizations. Of the total of 64 international organizations, one is concerned mainly with the entire field of mass communication. There are 31 international press organizations, 22 film, nine broadcasting, and one television. Part II lists 1049 national organizations. Of this number, 561 are press organizations, 341 film, 134 radio, and 13 television.

From Tin Foil to Stereo

By Oliver Read and Walter L. Welch. Published (1960) by Howard W. Sams & Co., 1720 E. 38 St., Indianapolis 6. 524 + xvi pp. Illus. Appendix. Index. 6 by 9-in. Price $9.95.

Beginning with the statue of Memnon at Thebes and ending with a discussion of stereo discs, *From Tin Foil to Stereo* spans more than 3000 years of human endeavor to imitate or reproduce natural sounds by mechanical means. The book is, as the title suggests, mainly concerned with the evolution of the phonograph since its invention in 1877 by Thomas A. Edison. The book is also about America, American business practices in the late 19th and early 20th centuries, and some of the legal mazes and bypaths stemming from the invention and development of the phonograph.

The book is not only documented with amazing thoroughness, making it a valuable source of reference material, it is also a delight to read. Not the least of its delights is the hundreds of photographs some of which, the authors state, are reproduced for the first time. For lovers of

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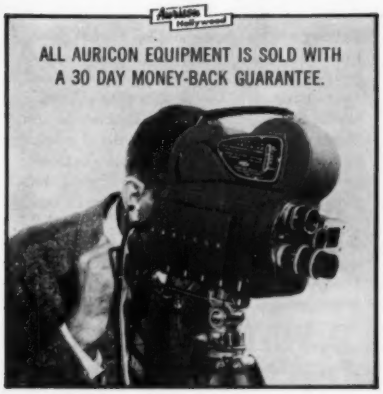

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Americana and of "the good old days" there is a wealth of historic and (to some) nostalgic material. One of the most amusing illustrations is in the Appendix (p. 479) showing the title page of "The Song of Mister Phonograph" (copyrighted 1878). A robot-like creature whose head is a cylinder capers in music-hall style.

The book is full of references and quotations, and names of inventors, attorneys, businesses, singers, musicians — some long-dead, others very much alive, and others alive in history and memory — march through the pages. Old law suits, decided long ago, are recounted in detail, throwing new light on some of the judgments of history. For example, after a detailed account of the suit of Marconi Co. vs. DeForest Co. (pp. 229–231) the authors ask, "But the question remains, with respect to historical accuracy, to whom belongs the major credit for the initial and basic contribution of the first vacuum tube, Fleming or Edison? Edison had built the first tube, Fleming had discovered a new use for it . . .?"

The book is not one that can be read at one sitting, in spite of its highly readable style, but is rather a book that can be returned to again and again for entertainment as well as information. The authors have made a genuine contribution to the history of the United States by their careful and illuminating examination of the development of one invention.

Fundamentals of Photographic Theory

2d ed., completely revised, by T. H. James and George C. Higgins. Published (1960) by Morgan & Morgan Inc., 101 Park Ave., New York 17. 345 pp. incl. index, illus. and graphs. 5½ by 8¼-in. Price $7.50.

Fundamentals of Photographic Theory was first published in 1948. The second edition has been extensively revised and reset to include recent discoveries and developments. The book, which gives a general account of the theory of the photographic process, based on fundamental chemical a..d physical concepts, is used as a textbook in photographic courses in many colleges. In the second edition, extensive revisions have been made, particularly in the chapters on the photographic emulsion, formation of the latent image, mechanism of development, kinetics of development, and structure of the developed image. New information on the theory of color photography and color sensitometry is included and there is a description of the chemistry of the formation of dye images. A comprehensive list of references is given at the end of each chapter. A reader who requires more advanced or more detailed treatment of any phase of the photographic process will find an ample listing of source material from which he may select what suits his needs.

"The American Standard Requirements for Electrical Indicating Instruments: Panel, Switchboard and Portable Instruments" is published by American Standards Association, 10 E. 40 St., New York 16. This is Standard C39.1-1959, a revision of C39.1–1955. The development of this American Standard has resulted from the work of the Sectional Committee on Electrical Measuring Instruments C39. This specification is intended to assure that instruments conforming to it will be satisfactory for general industrial use.

British Broadcasting Engineering Monograph, *Programme Switching, Control, and Monitoring in Sound Broadcasting,* published February 1960, is No. 28 in a series which was begun in June 1955. About six monographs, each dealing with some phase of television and sound broadcasting, are published each year. Individual copies are priced at 5s; and an annual subscription is 1 £. Orders can be placed with BBC Publications, 35 Marylebone High Street, London, W.1.

Sound and Vision Broadcasting, if it maintains the high standard set by the first (Spring 1960) issue, will be a valuable addition to publications dealing with particular or overall aspects of the broadcasting field. It is published by the Broadcasting Division of Marconi's Wireless Telegraph Company, Ltd., Chelmsford, Essex, England. The aim, according to the Editor, R. L. Varney, "is to cover not only the engineering side of broadcasting but also that of programing, and to interest all those whose work may lie in either direction, whether sound or vision." The magazine will be issued three times a year. Translations in German and Spanish of the main articles are included. The first issue contains seven main articles and six brief news stories on installations throughout the world. The publication is enhanced by numerous illustrations.

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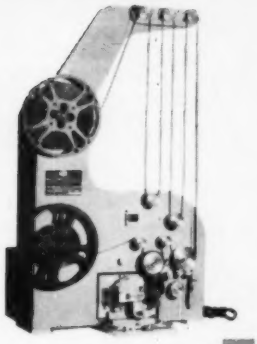

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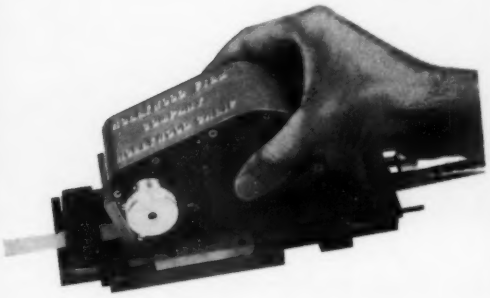

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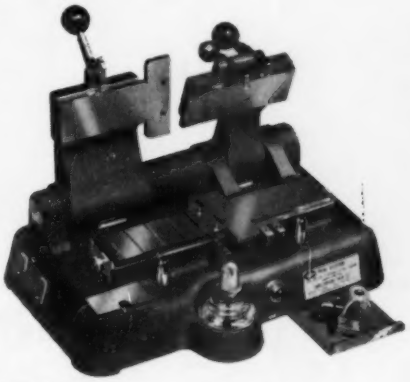

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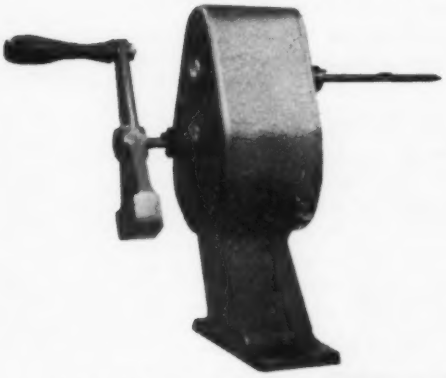

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section reports

The Atlanta Section met on March 8 at the Kodak Processing Laboratory with an attendance of 23. William Koch of the Motion Picture Film Dept., Eastman Kodak Co., New York City, was the guest speaker. His subject was "New Eastman Reversal Color Products of High Emulsion Speed Characteristics." To describe the new Eastman Ektachrome ER films, slides were shown that illustrated the physical and sensitometric characteristics of the film, processing methods and printing systems that can be used if release prints are desired.

Demonstration films were shown of some of the typical uses expected of the new films. It was stressed that this film is a new and additional product and not a replacement product. Mr. Koch answered general questions during the meeting. After the meeting, members of the Section were able to discuss specific problems with him.

Attendance at the meeting was not very large, but those attending felt that they had obtained some very practical information for use in their work. After the meeting, coffee and doughnuts were served and a tour of the Kodak Processing Laboratory was conducted.—Wesley R. Sandell, *Secretary-Treasurer*, c/o Kodak Processing Lab., 4729 Miller Drive, Chamblee, Ga.

The Dallas-Fort Worth Section met on March 3 at the WFAA-TV Studios in Dallas with an attendance of 40. Cyril Teed, Research Engineer of Marconi Wireless Telegraph Co., the guest speaker, discussed "The 4½-in. Image-Orthicon" and the camera channel for the same.

Mr. Teed gave the history of the development of the 4½-in. image-orthicon and then went into considerable detail in describing the development of the camera chain. The information was comprehensively presented and the technical phase was well done. An informal demonstration of the camera chain followed the speaker's remarks. A commercial was video taped and played back using the camera chain.

The meeting generated a lively discussion period after which coffee and doughnuts were served.—M. D. McCarty, *Secretary-Treasurer*, c/o Magnolia Petroleum Co., P. O. Box 900, Dallas, Tex.

The Hollywood Section met on March 15 with an attendance of 275. Eliot Bliss, the guest speaker, gave an excellent demonstration of the various means by which video tape, film and tape-to-film transfers are all contributing to current television production. Comparisons of TV picture quality were made among the three media — film, tape and tape-to-film transfers — with particular emphasis on recent quality improvements that have been made in photographic recording of television.—Ralph E. Lovell, *Secretary-Treasurer*, 2554 Prosser Ave., Los Angeles 64.

The Nashville Section met on December 5 at the WLAC-TV Studios in Nashville with an attendance of 41. Guest speakers were Ralph Hucabee, WLAC-TV; Aaron Shelton, WSM-TV; and Frank McGeary, M-P Laboratories, Inc.

Session moderator, Anton Pilversack of TRAFCO, introduced the subject for discussion: "What Constitutes a Good Television Print?" The panel of speakers presented ideas and standards from the viewpoint of their own particular divisions of the 16mm industry.

Following the presentations for TV stations by Messrs. Hucabee and Shelton and for the laboratory side by Mr. McGeary, the entire group discussed the problems from the producer's point of view. As a part of the program there were two closed-circuit runs of a series of TV prints illustrating the range of contrast that can be produced from the same original, by experimentation in both the dupe negative and positive stages.

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illustrated good TV projection quality.—Frank M. McGeary, *Secretary-Treasurer*, c/o M-P Laboratories, Inc., 781 S. Main St., Memphis 6, Tenn.

The Nashville Section met on January 16 at the Studios of Baptist Sunday School Board in Nashville with an attendance of 21. Gordon Tubbs of Eastman Kodak Co., the guest speaker, discussed "New High Speed Ektachrome Films."

This was one of the best meetings to date according to audience reaction. Following Mr. Tubbs' talk, there was a demonstration of the film possibilities by projecting samples. The question-and-answer period after the speaker's formal presentation branched off into the realm of new discoveries in films, equipment and processing, with possible applications to the future of the industry. This proved to be of tremendous interest and the meeting had to be forcibly terminated after several hours. Several new members were signed to SMPTE at this time.—Frank M. McGeary, *Secretary-Treasurer*, c/o M-P Laboratories, Inc., 781 S. Main St., Memphis 6, Tenn.

The New York Section met on March 9th at the World Affairs Center Auditorium, Carnegie Endowment Center, with an attendance of 212. Guest speaker Calvin S. McCamy, Chief, Photographic Technology Section, Optics and Metrology Division, National Bureau of Standards, discussed "Demonstration of Color Perception with Abridged Color Projection Systems."

Mr. McCamy traced the development of color theory through the "classical period" ending in 1802 and then outlined the refinements made since that time to account for object color perception. He quoted from extensive literature (Maxwell, 1855, Ducos de Hauron, 1895) and drew attention to the Helson-Judd formulation published in the Journal of the Optical Society of America which permits computation of the colors perceived when scenes of any sort, including two-color projections, are viewed.

The visual effects of simultaneous and successive contrast, object-color constancy, and memory were strikingly demonstrated by means of simple spots of light and pictures. The way in which these effects contribute to color perception was indicated. Colored pictures and charts were shown by three primaries and by two primaries, one of which was usually incandescent-lamp light as most recently described by Dr. Land.

A number of people in the audience reported seeing color in a black-and-white picture projected by incandescent-lamp light. This phenomenon, which occurred when a picture of familiar grocery items was projected at a very low luminance, was attributed to the effect of memory on perception. After showing rather realistically colored pictures of the familiar grocery items by two-primary projection, the speaker demonstrated the failure of this system to reproduce certain pairs of colors and the difficulties encountered with exterior scenes with bright skies.—James W. Kaylor, *Secretary-Treasurer*, c/o Movielab Film Labs., Inc., 619 W. 54 St., New York 19.

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Two New *f*/1.9 Lenses for 16mm and Vidicon Cameras

By G. H. AKLIN

WHEN Eastman Kodak Company announced the 16mm, 100-ft spool camera (the K-100), it also introduced two new *f*/1.9 Cine Ektar lenses, a 25mm lens and a 50mm lens. These give improved resolution in accordance with requirements of 16mm motion-picture production, and are exceptionally well suited for professional work. The field covered by these lenses is adequate for use with the vidicon tube.

Along with improved resolution, these lenses are matched in spectral transmission so that, in changing from one lens to another, there is no appreciable change in color balance when using color film. They can be fitted to any camera by means of suitable adapters. All air-glass surfaces are, of course, hard-coated and suitable baffling is employed to give maximum image contrast and freedom from flare.

For many years the standard lens on Kodak 16mm Cine Cameras was a 25mm *f*/1.9 objective of the modified Petzval type. In spite of some shortcomings, this lens was very successful and many thousands were manufactured. In 1948, two Cine Ektar lenses of improved construction were announced*; a 25 mm *f*/1.4 of the 4-component 7-element meniscus type, and a 4-element 25mm *f*/1.9 lens, offered as a lower-priced substitute. Both lenses gave much better resolution than the original Petzval type.

Since the introduction of these lenses, the quality of 16mm motion pictures has advanced to the point where a better *f*/1.9 lens is needed. To meet this requirement, a new 25mm *f*/1.9 and a new 50mm *f*/1.9 have been designed. These lenses were introduced when the Kodak K-100, 16mm, 100-ft spool camera was announced.

A sketch of this new 25mm lens (Fig. 1) shows its spherical aberration and field curves. It is of a 4-component meniscus type with 6 elements, in four of which the Kodak high-index glasses are used. The lens is described in U.S. Patent 2,682,198, June 29, 1954. It is designed to cover a 16mm motion-picture frame (13.7° half angle) and also the photosensitive surface of the vidicon tube (16½° half angle).

Lens bench examination shows that the star images of this lens at full aperture have a diameter of 0.006mm on the axis, and expand to within 0.012mm at the 14° point. At 16½° this has reached 0.018mm. The results of a photographic test using a high-contrast resolution chart (1000:1 luminance ratio) at a reduction of 50:1 on three different emulsions are given in Table I. The published resolution values obtained on the lenses announced in 1948 were made using an emulsion that is no longer manufactured, therefore it would not be practical to make a direct comparison with the new lenses. The relative illuminations at 13½° and 16½° are also shown in Table I.

Table I. Resolution Figures of a Photographic Test for the 25mm f/1.9 Using a High Contrast Chart (1000:1 Luminance Ratio) at a Reduction of 50:1 on Three Different Emulsions.

16mm Films	*f*/	Axis	4½°	9°	13½°	Vidicon 16½°
Kodachrome Movie Film Daylight Type 5263	1.9	63	50	40	32	25
	8.0	63	50	50	40	25
Eastman Background-X	1.9	63	50	50	32	25
Pan. Negative, Type 7230	8.0	80	63	63	40	25
Eastman Plus-X	1.9	100	80	63	50	32
Reversal, Type 7276	8.0	100	80	80	63	32
Relative Illumination					60%	40%

Table II. Spectral Transmission of Both the 25mm and the 50mm Lenses.

	25mm	50mm
400	78%	68%
450	86	82
500	88	88
550	86	88
600	83	87
700	80	83

Table III. Resolution Figures of a Photographic Test for the 50mm f/1.9 Using a High Contrast Chart (1000:1 Luminance Ratio) at a Reduction of 50:1 on Three Different Emulsions.

16mm Films	*f*/	Axis	2½°	4½°	6½°	Vidicon 8½°
Kodachrome Movie Film, Daylight Type 5263	1.9	40	40	40	32	25
	8.0	63	50	50	50	40
Eastman Background-X	1.9	40	40	40	40	32
Pan. Negative, Type 7230	8.0	63	63	63	50	40
Eastman Plus-X	1.9	80	63	63	63	40
Reversal, Type 7276	8.0	100	80	80	80	63
Relative Illumination					77%	70%

The 50mm f/1.9 Lens

In color photography, the transmission in the blue-violet region between interchangeable lenses on a camera must be closely matched to each lens. It can readily be seen that if this transmission should vary beyond tolerable limits, the color balance would then be noticeably disturbed when changing from one lens to another. One may justifiably assume that a lens having twice the focal length of another lens of the same type would also have twice the glass thickness, and therefore would be expected to show a loss in blue transmission. For this reason the 50mm *f*/1.9

This paper was presented on October 5, 1959, at the Society's Convention in New York, by the author, who is with the Apparatus and Optical Div., Hawkeye Wks., 20 Ave. E, Rochester 4, N.Y. This paper was received on March 19, 1959.

* Rudolf Kingslake, "New series of lenses for 16mm Cameras," *Jour. SMPTE, 52:* 509–521, May 1949.

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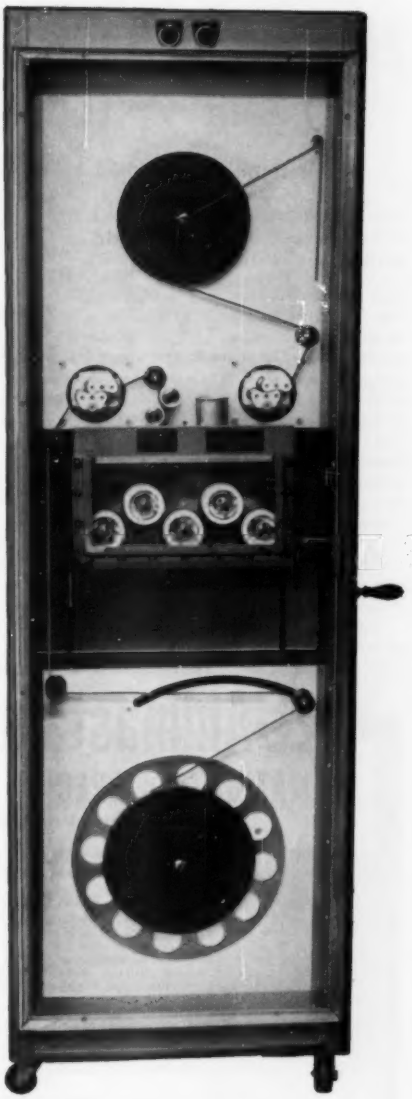

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The Model A-5100 is a combination 16/35 mm film cleaner. Other cleaners are available for 16 mm film only, 35 mm film only and for 70 mm film only. All models include these special features:

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FLUID CUSHION PROTECTS FILM. *The fluid solvent forms a barrier between the scrubbing roller and film to prevent scratches and abrasions. Only velvet fibres lightly touch the film.*

SPEED CONTROL. *Operate at any speed from 0 to 300 feet per minute with adjustable speed control. Automatic shut-off leaves unit threaded for continuous operation.*

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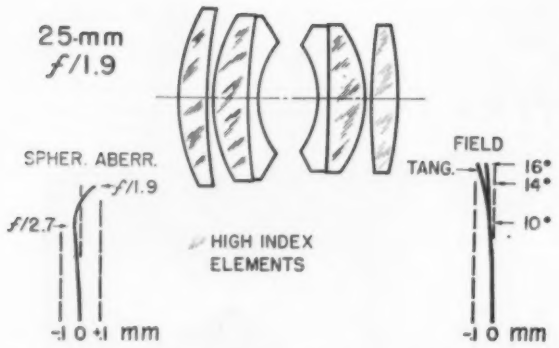

Fig. 1. A sketch of the new 25mm f/1.9 showing the character of its spherical aberration and field curves, and the location of the high index glasses used.

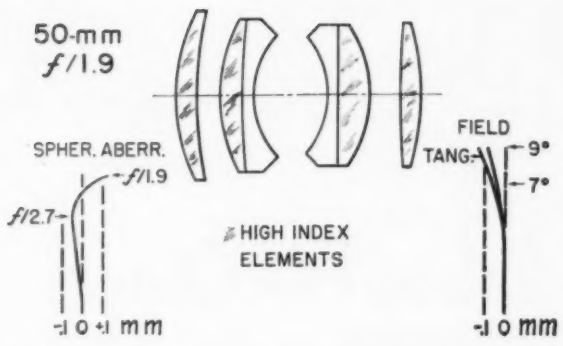

Fig. 2. A sketch of the new 50mm f/1.9 showing the character of its spherical aberration and field curves, and the location of the high index glasses used.

lens could not be merely scaled up from the 25mm formula, but had to be a new design. Requirements include thinner elements and, where permissible, more transparent glasses so that the total absorption would match that of the 25mm formula. Since this lens must cover 9° as against 16½° for the 25mm design, certain of these changes are possible and the desired results could be obtained without sacrificing definition. Figure 2 shows this new formula along with its spherical aberration and field curves.

Figure 3 shows the comparable thickness differences between these two lenses, drawn to the same scale.

Table II gives the spectral transmission of both the 25mm and 50mm lenses.

Lens bench examination shows that the star images of this 50mm lens at full aperture have a diameter of 0.015mm on the axis, and increase to about 0.022mm at 7°, and to 0.030mm at 9°. Table III gives resolution figures in a photographic test similar to that for the 25mm *f*/1.9 lens.

In modern practice, all air-glass surfaces are hard coated, and suitable baffling methods are employed. The result is that a minimum of light is lost in surface reflections and images have maximum contrast free from flare.

Both the 25mm and 50mm lenses are available in S and C mounts. The 25mm lens can be focused from 12 in. to infinity and the 50mm lens from 24 in. to infinity.

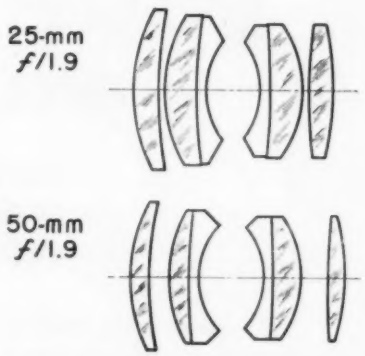

Fig. 3. The comparable glass thickness differences between the 25mm and the 50mm lenses drawn to the same scale.

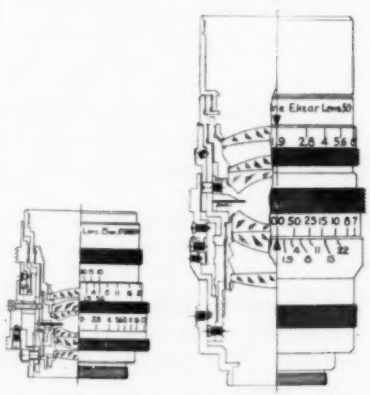

Fig. 4. Quarter section drawings of the 25mm and 50mm lenses in C mounts.

The new-type diaphragm wings are used so that an extended diaphragm scale for the small apertures is obtained, the smallest aperture in both cases being *f*/22. All mounts have click stops and depth-of-field scales. Figure 4 shows a quarter section of both the 25mm and 50mm lenses in C mounts.

The assistance of my colleagues who furnished drawings and data in the preparation of this paper is gratefully acknowledged.

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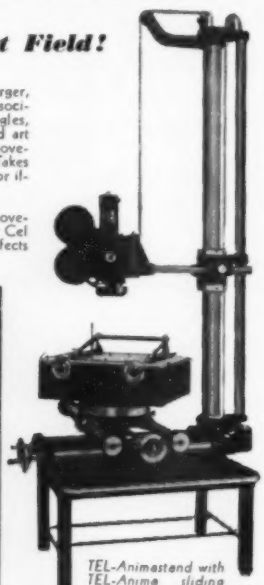

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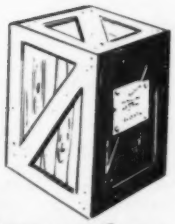
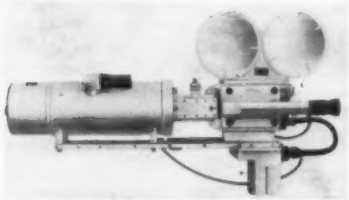


new products

(and developments)

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products or services.



The Cameraflex 35mm boresight camera designed to photograph the target being tracked by a radar set is distributed by Camera Equipment Co., 315 W. 43 St., New York 36. The camera has a register pin movement and a reflex shutter principle whereby the action may be viewed through the taking lens while the camera is in operation. A variable shutter mechanism allows a maximum of 60° and a minimum of 1¼° opening. The shutter mechanism is driven through a differential drive which controls a return pulse contractor, giving a return pulse at precisely midpoint, regardless of the degree of shutter opening.

The camera is driven by a synchronous motor which operates the camera at a constant speed of 24 pictures/sec. It can also operate at a rate of 10 pictures/sec, 20 pictures/sec, or 30 pictures/sec. It can also use a pulse-driven speed up to 10 pictures/sec. A built-in data recorder allows the recording of binary coded information. Binary coded words, timing data and event marking pulses can be fed through the data recorder on separate tracks.

Other features include either 40-in. or 80-in. catadioptric lens, 200-ft or 400-ft magazines, gear driven by a separate torque motor; a radar-secondary mount with provisions for azimuth, elevation and camera-focusing adjustments.

70mm data recording motion-picture films are being studied by Technicolor Corp., 6311 Romaine St., Hollywood 38, with a view toward possible modification of one of the processing machines to accommodate 70mm data recording films in both color and black-and-white. Most of these films carry 1956 ASA Type I perforations. The firm has, for several years, been engaged, among other activities, in the production of 70mm color release prints. Fred H. Detmers is in charge of information for prospective users of the system.

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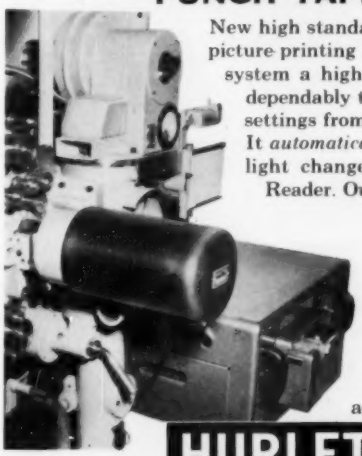

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Program intelligence control tape produced on the Hurletron Dial-Matic Perforator provides a permanent accurate control of all necessary printer, fader and shutter functions. The Hurletron Tape Reader can also be adapted for use with any punch tape code.

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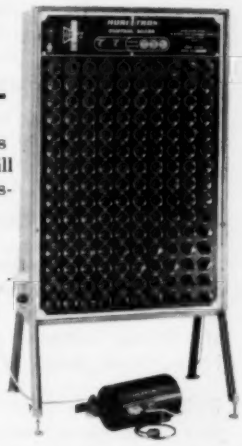

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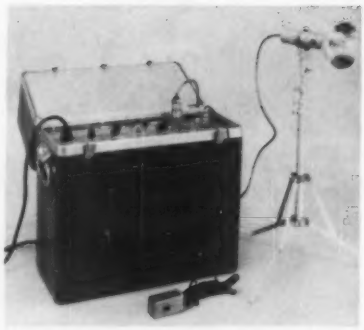
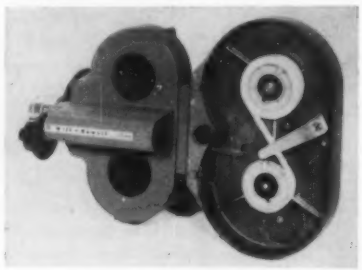


An electronic flash unit, Model 357, developed primarily for use with the Model 326 Dynafax High-Speed Camera has been announced by Beckman & Whitley, Inc., 973 San Carlos Ave., San Carlos, Calif. A compact portable unit, designed to be easily handled, it has a 1200-w/sec capacity which gives sufficient light intensity to cover an area up to 2 sq ft with 1-μsec exposure. The duration of the flash can be controlled to correspond to the writing time of the camera. Waveform of the light pulse is square to provide even illumination on all frames. Duration settings are 8.70, 11.15, 14.75, and 22.25 msec. Rise and decay times of the pulse are in the order of 40 msec. The flash unit may be triggered from a normally open or normally closed switch, positive pulse, or photoelectric cell. An additional feature is a modeling light which operates at 60 flashes/sec for use in framing, focusing, and light arrangements. Operation is from a 115-v, 60-cps, 5-amp integral power supply. The flash unit is priced at $1950.



A system of processing motion-picture film within the camera, based on the use of chemically presaturated paper material, has been announced by Specialties, Inc., Skunks Misery Rd., Syosset, L.I. The system, called Rapromatic processing, involves the application of a processing solution to an emulsion by sandwiching the photographic material with a paper web saturated with chemicals. This paper web is called Raproroll. The process was developed specifically to enable quick access to recorded .data, instrumentation records and other industrial photographs. It is presently available on a production basis for 16mm film. In the magazine-processor, the Raproroll and exposed film or photographic paper are pressed together in intimate contact under nominal pressure. The paper releases its liquid under pressure and the liquid is accepted by the emulsion. The required quantity of solution is carefully controlled by web thickness and composition to prevent dripping. The film is immediately developed and can be projected on a screen in less than 60 sec after shooting. The process is distributed in the west by Traid Corp., 17136 Ventura Blvd., Encino, Calif.

A magnetic tape system capable of recording and reproducing both analog and pulse signals has been announced by Minicom Division of Minnesota Mining and Manufacturing Co., 2049 S. Barrington Ave., Los Angeles 25. The 7-track system, called the CM-100 Video Band Recorder/Reproducer, is packaged in a single, standard-size rack and offers selection of six speeds ranging from 7½ to 120 in./sec on single ½-in. tape. Each of the seven video tracks covers an overall bandwidth of 400 cycles to 1.0 mc with greater frequency response. Examples given in the announcement: 1.0 mc at 120 in./sec; 500 kc at 60 in./sec. Compactness of the system is achieved by combining electronics for both recording and reproducing in a single unit for each track.

The Sonocolor SCF 2 Striping Machine for the coating of magnetic tracks on motion-picture film is a product of Sonocolor, 54 Avenue de Choisy, Paris 13, France. The machine, designed for heavy industrial service, is used to apply full coating on unprocessed films and single- or multi-tracks on processed films after development. Requiring only one operator, the machine has an interchangeable coating head assembly so that films of all widths can be coated and one or several tracks can be deposited. The machine is completely self-contained and requires less than 11 sq ft of floor space.

The Communications Idea Center located at 5137 Broadway, Chicago, is a development of Wilding Inc., 1345 W. Argyle St., Chicago, producers of industrial motion pictures, and its subsidiary, Commercial Picture Equipment, manufacturer of portable equipment for business communications. The Center is equipped

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with an 18-ft turntable for demonstrations and presentations. Recent demonstrations include a punched-tape device for automatic control of a sales presentation by opening and closing curtains, turning lights on and off and starting and stopping projectors. Called Automatic Program Control (APC), it is designed primarily for field use. Among other presentations is the two-projector motion-picture technique on a wide screen, synchronized with right and left images, each with separate sound to permit conversation to be carried on between actors in both images. Other presentations include Trigger-Strip slidefilm to provide animation; Vista-Strip, a slidefilm device producing images that seem to flow across the screen, and Vista-Sell, a device for use in markets, railroad stations, airline terminals, using a moving color filmstrip.

The International Trade Fair (April 9–26) at Osaka, Japan, features a color Ampex Videotape Recorder in constant operation throughout the Fair, recording and playing back immediately the appearance of Japanese and American celebrities and representatives of other countries attending the Fair. The studio at the Osaka Fair utilizes a General Electric color camera as the program source for the recorder. Closed-circuit demonstrations are scheduled for broadcast over television stations in Osaka. In addition to recordings made within the studio, a number of prerecorded color tapes are being used for closed-circuit playback for visitors to the Fair.

A magnetic tape recorder that automatically changes tape cartridges was demonstrated by the inventor, Marvin Camras, senior engineer at the Armour Research Foundation of Illinois Institute of Technology, at the annual convention of the Institute of Radio Engineers, March 17, in New York. The cartridge, 3¾ in. in diameter, contains a ¼-in. magnetic tape with leader tapering from 0.25 in. to 0.34 in. Its central opening fits present recorders. The cartridge is said to be universal in respect to speed, tape width, and single- or multi-channel operation. On the inner side of each flange of the cartridge, a bead is molded which holds a wide Mylar end-leader securely in place, sealing the inside to protect the tape from dust. The ¼-in. recording tape passes through the flanges with ample clearance after the leader has been unwound. A leader at the inner hub actuates the automatic reverse or rewind operation.

Protection against accidental erasure is provided by a safety groove in the bottom of the cartridge. If this groove is present, a "feeler" enters it when the machine is switched to recording position, allowing normal erasing or recording. Unrecorded cartridges are molded with this groove; recorded cartridges are not. A removable insert is provided, so that protection may be added after a cartridge has been recorded.

A member of the Society, Mr. Camras is the author of several papers published in the *Journal*, including "Magnetic Sound for Motion Pictures" (pp. 14–28, Jan. 1947), and "Magnetic Sound for 8mm Projection" (pp. 348–356, Oct. 1947).

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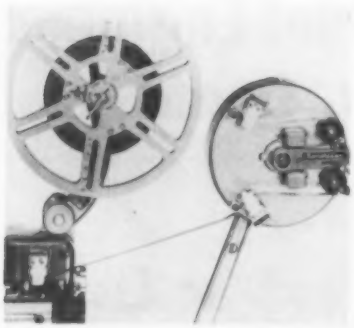
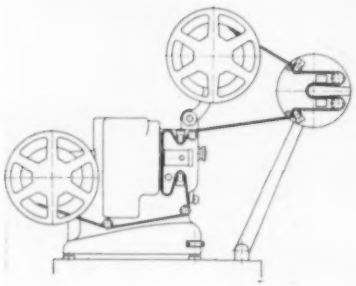
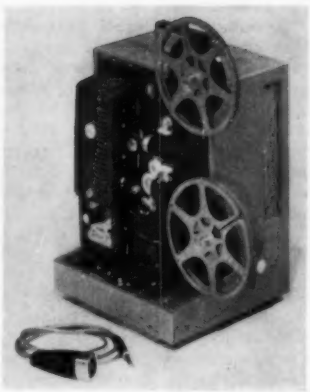




The Bolex Sonorizer, a magnetic sound unit for recording and playing back sound directly on 8mm film has been introduced by Paillard, Inc., 100 Sixth Ave., New York 13. To be used in combination with the Bolex M-8 and many other 8mm projectors, the unit features two separate inputs connected to a built-in mixer, and an automatic fade-out and overplay device for superimposing one sound over another on a single recording track. The unit records the sound on a 30-mil-wide magnetic stripe applied to the edge of the film outside the perforated holes after the film is processed. The point of recording and playback is at the soundhead which forms a "third reel," the film traveling through it before entering the film gate. The soundhead works on the pull-through principle. The film passes over a sound roller which maintains even pressure against it by means of a set of double pendulum rollers. The sound roller drives a dynamically balanced flywheel inside the soundhead. The unit, complete with case weighs 28½ lb and measures 10 by 12 by 14 in. It is priced at $250.

An 8mm sound motion-picture projector incorporating a complete system for recording and playing back magnetic sound on both old and new 8mm film has been announced by Eastman Kodak Co. and is the subject of a paper scheduled for presentation at the forthcoming Convention in Los Angeles. The projector has a number of unusual features. The magnetic head used in the sound system is made of a new metal called Alfenol which has an estimated life span of thousands of hours. The magnetic head is only 20 mils wide — less than the width of the magnetic striping — to eliminate "edge tracking" and to assure better sound quality. A non-axial



500-w projection lamp is used to provide illumination for screenings five feet wide, and a lower light level of 250 w can be used when recording. The operator can erase, re-record, or playback sound at will.

There are two basic controls for the sound system, a play/record switch and a volume control knob. For projection, separate switches are supplied for motor and lamp, and a single rotary switch controls forward and reverse projection, "stills," and power rewind. The projector is priced at $345.

A new Kodak Sonotrack Coating service for processed 8mm Kodachrome film has also been announced. The magnetic oxide coating is applied between the film edge and perforations of the processed film.

Also announced is a self-threading 8mm projector, the Brownie 8 Movie Projector (Model A15). A pulldown claw and a fixed film guide assembly lead the film through the gate and onto the 200-ft take-up reel. The projector is priced at $54.50.

A variable-focus lens with a range of 20mm through 80mm has been announced by Traid Corp., Box 648, 17136 Ventura Blvd., Encino, Calif. The lens will fit any 16mm camera with a "C" mount. The lens is 4½ in. long with a diameter of 2 in. The iris is constant at *f*/2.5 for all focal lengths. The focusing scale is 48 in. to infinity. Price of the lens is $335.00.

A line of projection lenses for 8mm and 16mm projectors is designed and manufactured by J. H. Dallmeyer, Ltd., Willesden, London, N.W. 10. Ranging in length from 20mm to 102mm, and with some two dozen different mounts, the lenses are described in a set of leaflets available upon request from the firm. The London firm is now in its one hundredth year. In 1860 the founder of the firm, John Henry Dallmeyer, was granted a patent for a Triple Achromatic lens consisting of three cemented doublets.

The Rondo 8mm Movie Editor has been announced by Service Photo Suppliers, Inc., 33 E. 17 St., New York 3, distributor for Rondo Products, Japan. The editor features winding arms, folding flat against the housing for easy storage, with a full 400-ft reel capacity. The forward crank has a 1:1 ratio and the rewind crank has a 3:1 ratio. It is priced at about $34.95.

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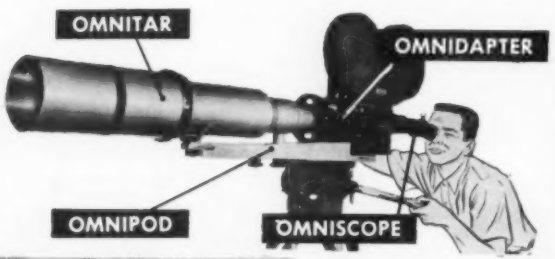

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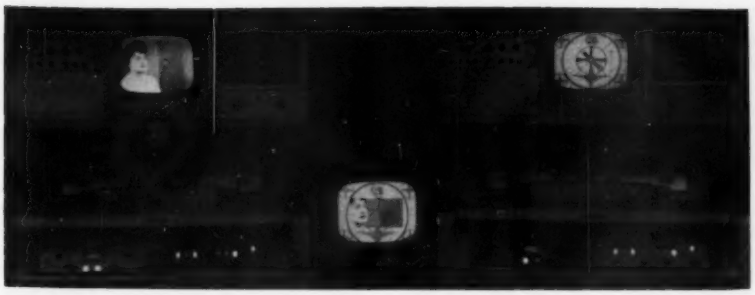
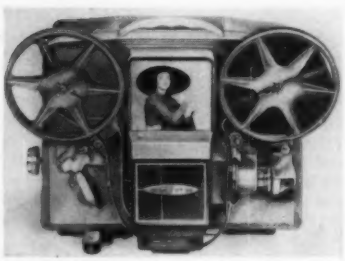


A device called Inter-Sync is used to combine the output of two or more Ampex Videotape Recorders in precise synchronization. Announced by Ampex Professional Products Co., Video Products Div., Redwood City, Calif., the unit replaces the standard drum servo unit in the Ampex recorder. In addition to combining the output of the recorders, the Inter-Sync will synchronize the playback of one or more recorders with the output of camera, film chain, network feed or other signal source. The device is said to lock the playback of a tape machine horizontally, line for line, to other TV sources as well as vertically, field for field. This permits electronic editing of TV tape and suggests numerous special effects applications.



A two-purpose 8mm projector called the Kalart VP-88 shows movies on a built-in viewer as well as on a projection screen. Introduced by Kalart Co., Plainville, Conn., the device has a control lever which is used for forward and reverse when projecting on a screen, and forward, reverse and still when projecting on the built-in viewer. The picture can be switched from screen to viewer while the projector is in operation by means of a viewer lever. It is priced at $89.50.

A 70mm lens attachment for the Camex 8mm single-lens reflex camera has been announced by Karl Heitz, Inc., 480 Lexington Ave., New York 17. The attachment, called the Retro-Zoom is used to convert the varifocal Angenieux-Zoom lens from 17.5–70mm $f/2.2$ to 12.5–50mm for a zoom range from standard lens to a telephoto lens of 6× magnification. The attachment permits focusing from infinity down to 2½ ft. It is priced at $99.00.

The Weston Master IV, an exposure meter designed to combine sensitivity with rugged construction, has been announced by Weston Instruments Division of Daystrom, Inc., 50 Church St., New York. Features include a simplified exposure dial using only numbers found on modern cameras; on-off pointer lock, and a converter for incident light readings. While the meter can be used conventionally with free pointer movement, the on-off button permits locking the pointer when taking incident light readings, for instance, in extremely low light locations.

A storage cabinet for video tape has been announced by Neumade Products Corp., 250 W. 57 St, New York 19. The units accommodate 6-, 8-, 12½- and 14-in. tape reels. Facilities for library storage, transient editing and "on the air" program filing are included.

Accessories for home or amateur use produced by Kalimar Inc., 1909 S. Kingshighway, St. Louis 10, include the Minette 8mm Viewer-Editor and the Kalimar Auto Memo Exposure Meter. The viewer-editor features a 2½ by 2-in. frame area, simplified threading and built-in marking device. It is priced at $34.50. The exposure meter features a built-in "memory" indicator that holds the light reading as long as desired. It is priced at $14.95.

Two models of a "thin-trim" inconspicuous professional microphone have been introduced by Electro-Voice, Inc., Buchanan, Mich. The E-V 652 and 652A are dynamic-type microphones with a length of semirigid tubing to bring the microphone close to the user while the stand remains out of the way. The microphone can be tilted through a 120° arc with respect to the stand coupler. Two clear plastic baffles that fit on the head of the microphones are provided to add directivity and boost brilliance at the 6000-cps range. Model 652 has an overall length of 24 in. and weighs 10 oz. The 652A is 15 in. long and weighs 8 oz. The long necks are of a nonreflecting Nicaloy finish and are $\frac{3}{16}$ in. in diameter. Both microphones have an output level of −60 db and are designed to match all low-impedance inputs. A UA3-12 cable connector, 20 ft of three-conductor shielded cable and Model 300 stand coupler are included. Each of the microphones is priced at $120.00.

A monochrome television camera utilizing a 4½-in. image orthicon has been announced by Radio Corp. of America. Designed for stability and simplicity of operation, the camera employs only

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two main operating controls. Essentially all setup controls are located within the camera rather than in a separate master console. Even with the centralized controls the camera weighs only 130 lb. Nuvistor tubes (p. 358, May 1959 *Journal*) are used in the video preamplifier and elsewhere. The camera chain includes a self-contained intercom with its own power supply. This may be interconnected with the studio intercom system or operated independently. The big picture tube involved the use of a large target and a relatively small photocathode, the same size as the photocathode on the 3-in. tube, so that the lenses on the new camera need be no larger than those on preceding ones. Electronic magnification produces the large image at the target, resulting in a corresponding increase in picture resolution for finer detail.

A new testing device, the ServiShops Motion Analyzer Mark III, used for testing all types of photographic equipment, has been announced by National Camera Repair School, Box 174DO, Englewood, Colo. Two other items, a collimater (lens-testing device) and a low-priced photoflash synchronization tester called the ServiShops Syncrotester have been announced.

A closed-circuit paging system, a development of Giantview Television Network, 901 Livernois, Ferndale 20, Mich., connects Convention Hall in Atlantic City, N. J. with all rooms in major hotels and motels in the area. Main use of the system is that of paging convention delegates. Paging requests are processed through a center in Convention Hall. Names of persons being paged are typed on cards bearing sponsor identification and placed on a drum. Rotation will allow for 7-sec exposure of each name being paged until the page is answered by a call to the center. The system is also used for special programs, announcements, and advertising.

Microphone Facts is a monthly newsletter written by Lou Burroughs, Vice-President of Broadcasting and Recording Equipment, Electro-Voice, Inc., Buchanan, Mich., containing discussions of individual problems, new ideas and developments. The January newsletter discusses unidirectional microphones. Copies of *Microphone Facts* may be obtained by writing to Mr. Burroughs.

The 5th edition of the Mood Music Catalogue has been issued by Thomas J. Valentino, Inc., 150 W. 46 St., New York 36. The catalog is designed for easy reference and provides details and descriptions for each recording, including timing, specific purpose of each cut, a brief description of theme, mood and tempo, and rates. The catalog is available upon request to the company.

Space Data Inc., 8921 Sepulveda Blvd., Los Angeles, has been appointed sales distributor for the closed-circuit television equipment of the GPL Division, General Precision Laboratory Inc., Pleasantville, N.Y.

Four- and six-channel magnetic theater sound systems are described in a four-page illustrated brochure published by Ampex Professional Products Co., Audio Products Div., 934 Charter St., Redwood City, Calif., and available upon request. The brochure emphasizes the use of six-channel stereophonic sound for 70mm wide-screen production. Details are given on the compact station control units designed to simplify operating procedures. These simplified control units were the subject of a paper by George B. Goodall, "Modern Control of Theater-Sound Equipment," presented at the Society's 1959 Fall Convention in New York, and published in this issue of the *Journal*.

The Labmaster Film Processors are described and illustrated in a brochure issued by Houston Fearless Corp., 11801 W. Olympic Blvd., Los Angeles 64. The three basic black-and-white models, all of modular construction, are the negative-positive (16mm or 16/35mm); reversal (16mm), and microfilm (16mm or 16/35mm). The brochure is available upon request.

The Audio-Visual Equipment Catalog #297 is available from Genarco Inc., 97-04 Sutphin Blvd., Jamaica 35, N.Y. Various types of equipment are described and illustrated including 3000-w slide projectors and electric slide changers for 3¼ by 4-in. slides.

A four-page price list for the company's line of TV broadcasting, repeating, microwave and communications systems is available from Adler Electronics, Inc., One Le Fevre Lane, New Rochelle, N.Y.

The Optics of Projection, No. 8 in the series of bulletins issued by National Carbon Co., Division of Union Carbide Corp., 30 E. 42 St., New York 17, discusses important points to be considered in correlating the light source with the optical system. The 8-page bulletin contains 19 illustrations. The discussion considers first the Formation of the Image on the Screen; and second, Illuminating the Wide Film Aperture and Film.

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These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Technician, Timer. Age 35, 12 yrs experience in all phases laboratory work, processing supervision, sensitometric control, some knowledge camera work and animation. SMPTE member. Desire permanent position with laboratory or TV station. Complete resume on request. Gunter J. Hackert, c/o Oskar Ernst, 213 East 81 St., New York 28.

Cinematographer. 25 yrs experience black-and-white and color, 35 & 16mm; 5 yrs theatrical production in Europe; 20 yrs industrial, commercial, educational and documentary films; recently worked 12 yrs with General Motors Audio-Visual Photographic Dept.; further background information available. Desires connection with producer of industrial, educational or travel films. Free to travel; speak several languages. J.P.H., Box 375, College Park Station, Detroit 21, Mich.

Producer-Manager or Laboratory Production Supervisor. Independent producer in 16mm sound films and industrial and color still photography desires position with large company. No capital to expand plus limited market prompts move. Married, 28 yrs old. B.A. and part M.A. in communications. Experienced PR man. Ex-Marine. Best of references. Owns complete motion-picture and still production and lab equipment. Résumé on request. Write: DH, Box 118, Missoula, Mont.

Writer-Director-Film maker, winner of numerous national and international awards and experience in entertainment, TV, industrial, and educational fields desires challenging assignment. Write 12625 Hatteras St., North Hollywood, Calif., or phone YUcca 2-2910, Santa Fe, N.M.

Television Producer-Director. With a broad background in both educational and network level commercial television. Experience in radio production and sales, and also a knowledge of merchandising. Both B.A. and M.S. degrees. Currently employed, but willing to move to a position where hard work and ability will lead the way to opportunity. Willing to locate anywhere in the U.S. Married. Résumé and references supplied on request. Write: Richard R. Ferry, Apt. 112, 14 Buswell St., Boston, Mass.

Motion-Picture Production Associate. Univ. S. Calif., Dept. of Cinema, graduate, age 26. Experience as cameraman, editor and sound mixer with National Educational Television and Radio Center at Univ. of Illinois Math Study. One yr project ends July 1, 1960. Desire permanent position as cameraman, editor or sound mixer. Resume and references on request. John A. Werner, 317 S. Russell St., Champaign, Ill.

Positions Available

Instrument Design Engineer. To assist with the design of high-speed motion-picture cameras and related products. Degree required in mechanical or electrical engineering with four yrs minimum design experience. A challenging position with a growing company. Write: T. H. Truesdell, D. B. Milliken Co., 131 N. Fifth Ave., Arcadia, Calif.

Television Engineer. GS-855-12, $8810 per yr. To plan, design, coordinate, test and evaluate television equipment for military applications. Position will require about 50% traveling within and possibly outside continental limits of U.S. Applicants must have either 4-yr academic engineering training with bachelor's degree, or equivalent experience or combination of college training and experience; in the latter cases a written test will be required. *Also,* **Sound Recording Equipment Operator Foreman** for TV Division, $4.09 per hr; **TV Video Equipment Operator Foreman** for Television Division, $4.25 per hr. For all positions, Standard Form 57 (Application for Federal Employment), obtainable from the U.S. Civil Service Commission or any Post Office, should be completed and sent to: Civilian Personnel Office, Army Pictorial Center, 35-11 35th Ave., Long Island City 1, N.Y. RA 6-2000, Ext. 238.

Equipment Technicians. To maintain, service, repair all types of mechanical and electronic production equipment. Excellent salary and opportunity to advance with expanding organization. Write fully, all letters kept in strict confidence: Arthur Florman, Florman & Babb, Inc., 68 West 45 St., New York 36.

Equipment Salesmen. To call on industry, government, film producers. Must be willing to travel. Excellent salary and opportunity to advance with expanding organization. Write fully, all letters kept in strict confidence: Arthur Florman, Florman & Babb, Inc., 68 West 45 St., New York 36.

Optical-Photographic Engineers. Excellent opportunities for optical and photographic engineers with or without experience in optical instrumentation, photographic optical systems and cinematography. Mechanical aptitude desired but not required for these engineering positions. Send resume to Ellis P. Faro, c/o Scientific Employment, Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y.

Photo Chemist/Chemical Engineer. Outstanding, creative opportunity for graduate chemical engineer or photo chemist with broad basic knowledge of processing techniques and solutions including minimum of 2 yrs experience with image transfer materials. Desire ambitious engineer with 10 yrs photographic experience for attractive opening in new product development. East coast location. Our employees know of this ad. Box MPTV 1944, 125 West 41 St., New York 36.

Sound Technician. GS-9, $5985 per yr. Duties involve operation, servicing and maintenance of complete 16mm sound recording system, including making of original magnetic tape recordings, rerecordings and optical recordings. Interested parties should apply by sending a resume or standard Government application form (Form 57) to Industrial Relations Department, Pacific Missile Range, Naval Missile Center, P.O. Box 4, Point Mugu, Calif.

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Contents — pages 272–298

News Columns

Space, Motion Pictures and Television (Tiros) . . 272

Fifth International Congress on High-Speed Photography—Senator Warren Magnuson 274

Education, Industry News 274

BOOKS REVIEWED 278
Principles of Optics, by Max Born and Emil Wolf reviewed by Pierre Mertz; *Professional Association in the Mass Media*, UNESCO; *From Tin Foil to Stereo*, by Oliver Read and Walter L. Welch; *Fundamentals of Photographic Theory*, by T. H. James and George C. Higgins; *The American Standard Requirements for Electrical Indicating Instruments: Panel, Switchboard and Portable Instruments*, ASA; *Programme Switching, Control, and Monitoring in Sound Broadcasting*, B.B.C.

Section Reports 284

Two New f/1.9 Lenses for 16mm and Vidicon Cameras, by G. H. Aklin 288

New Products 291

Employment Service 297

Advertisers

Arriflex Corp. of America 279
Bach Auricon, Inc. 281
Birns & Sawyer Cine Equipment, Inc. 294
Cameraflex Div., Federal Mfg. & Eng. Corp. . . 296
Camera Equipment Co. 276, 284
Camera Mart, Inc. 280
Classified 296
Computer Measurements, Inc. 289
Conrac, Inc. 293
Eastman Kodak Co. 273
Electro Powerpacs, Inc. 295
Electronic Systems, Inc. 291
Filmline Corp. 288
Florman & Babb, Inc. 287
Gevaert Photo-Producten N. V. 298
Hollywood Film Co. 283
Houston Fearless Corp. 285
Ichizuka Optical Industrial Co. Ltd. 292
Magnasync Mfg. Corp. 275
Motion Picture Laboratories, Inc. 297
Movielab Film Laboratories, Inc. 277
Peerless Film Processing Corp. 282
Professional Services 286
S.O.S. Cinema Supply Corp. 290
Westrex Corp. 278

Meeting Calendar

American Rocket Society, May 9–12, 1960, Ambassador Hotel, Los Angeles.
Society of Photographic Scientists and Engineers Annual Conference and Equipment Exhibit, May 9–13, 1960, Hotel Miramar, Santa Monica, Calif.
Society of Military Engineers, National Convention, May 16, 17, 1960, Washington, D.C.
ASME, Design Engineering Div. Conference, May 23, 1960, New York.
Design Engineering Show, May 23–26, 1960, Coliseum, New York.
Institute of the Aeronautical Sciences, National Summer Meeting, Mid-June, 1960, Los Angeles.
Acoustical Society of America, Spring Meeting, June 9–11, 1960, Providence, R.I.
National Society of Professional Engineers, Annual Meeting, June 9–11, 1960, Statler Hotel, Boston, Mass.
International Electronic, Nuclear and Cinematographic Exhibition, June 15–July 5, 1960, Rome, Italy.
AIEE, Summer General Meeting, June 19–24, 1960, Atlantic City, N.J.
American Society for Engineering Education, Annual Meeting, June 20–24, 1960, Purdue Univ., West Lafayette, Ind.
First Congress International Federation of Automatic Control, June 25–July 9, 1960, Moscow, U.S.S.R.
American Society for Testing Materials, Annual Meeting and Apparatus Exhibit, June 26–July 1, 1960, Chalfonte-Haddon Hall, Atlantic City, N.J.
AIEE, Pacific General Meeting, Aug. 8–12, 1960, San Diego, Calif.
Western Electronic Show and Convention, Aug. 23–26, Los Angeles.
European Conference on Electron Microscopy, Aug. 29–Sept. 3, 1960, Delft, Netherlands.
Standards Engineers Society, Sept., Pittsburgh, Pa.
Illuminating Engineering Society, National Technical Conference, Sept. 11–16, Penn Sheraton Hotel, Pittsburgh, Pa.
ASCE, National Convention, Oct. 9–13, Boston, Mass.
Electrochemical Society, Meeting, Oct. 9–13, Shamrock Hotel, Houston, Texas.
AIEE Fall General Meeting, Oct. 9–14, Chicago.
NEC National Electronics Conference, Oct. 10–12, 1960, Hotel Sherman, Chicago.
Optical Society of America, Annual Meeting Oct. 13–15, Somerset Hotel, Boston, Mass.
Fifth International High-Speed Congress and Equipment Exhibit, sponsored by the SMPTE, Oct. 16–22, 1960, Sheraton-Park Hotel, Washington, D.C.
Symposium on Space Navigation, Oct. 19–21, 1960, Columbus, Ohio.
Acoustical Society of America, Fall Meeting, Oct. 20–22, San Francisco.
AIEE, AIP, ONR, IRE, Metallurgical Society, Sixth Annual Conference on Magnetism and Magnetic Materials, Nov. 14–17, New Yorker Hotel, New York.
ASME, Annual Meeting, Nov. 27–Dec. 2, Statler, Hilton Hotel, New York.
89th Semiannual Convention of the SMPTE, May 7–12, 1961, King Edward Sheraton, Toronto.
90th Semiannual Convention of the SMPTE, Oct. 2–6, 1961, Lake Placid, N.Y.
91st Semiannual Convention of the SMPTE, Apr. 30-May 4, 1962, Ambassador Hotel, Los Angeles.
92nd Semiannual Convention of the SMPTE, Oct. 22–26, 1962, Drake Hotel, Chicago.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members appear in Part II of This Journal.

sustaining members

of the Society of Motion Picture and Television Engineers

The objectives of the Society are:

- Advance in the theory and practice of engineering in motion pictures, television and the allied arts and sciences;
- Standardization of equipment and practices employed therein;
- Maintenance of high professional standing among its members;
- Guidance of students and the attainment of high standards of education;
- Dissemination of scientific knowledge by publication.

Progress toward the attainment of these objectives is greatly aided by the financial support provided by the member companies listed below.

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The Society invites applications for Sustaining Membership from other interested companies. Information may be obtained from the Chairman of the Sustaining Membership Committee, Byron Roudabush, c/o Byron Motion Pictures, Inc., 1226 Wisconsin Ave., N.W., Washington 7, D.C.